Nigerian Journal of Engineering, Vol. 29, No. 2, August 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

Influence of Sesame Straw Ash on Splitting Tensile Strength and Durability of Concrete in an Acidic Environment

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

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

Research Article

Abstract

Large quantities of agricultural waste are generated annually, most of them unutilized or disposed to landfills causing severe environmental degradation. The usage of agricultural waste ashes as a partial replacement for cement helps to reduce the use of cement in concrete production, the emission of greenhouse gases from cement plants and environmental degradation. This study is aimed at assessing the influence of sesame straw ash as a partial replacement of Portland limestone cement (PLC) on the splitting tensile strength and durability of SSA concrete. Effects of SSA on concrete were investigated 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 curing age. However, after 28 days of curing in water, a total of fifty-four (54) cubes were cured in a 5 % concentration of H2SO4 solution for 3, 7, 28 days. Moreover, slump, water absorption and splitting tensile strength tests were carried out on the concrete, while the compressive strength test was carried out on SSA-concrete cured in H2SO4 solution. The results show that the workability and splitting tensile strength decreased as the SSA content increased. On the other hand, the splitting tensile strength increased as the curing age increased. Additionally, the compressive strength of SSA-concrete cured in a 5 % concentration of H2SO4 solution decreases as the portion of SSA content and curing age. The densities of SSA-concrete samples fall within the limits of 2200 kg/m3 to 2600 kg/m3. Finally, it was concluded that the SSA can be used as a partial replacement of cement in concrete.

Keywords

Cement; Durability; Sesame Straw Ash; Splitting Tensile Strength; Workability

Article History

Received: March, 2022 **Accepted:** May, 2022
Reviewed: April, 2022 **Published:** August, 2022

1. Introduction

The need to produce concrete from agricultural wastes cannot be over-emphasized. The use of supplementary cementitious materials (i.e. agricultural wastes) in the production of green concrete is hugely imperative in many conditions where there is a need to modify the characteristics of concrete. The use of supplementary cementitious materials (SCM) in buildings and other civil works has been testified to be efficient in conforming to the requirements of long-lasting concrete (Bakar et al., 2010). For the betterment of the characteristics of concrete and mortar, admixtures are added to the cement mixture, sourced either naturally from agro-produced or chemicals produced from industries, and most of the agro admixtures are pozzolans (Munshi et al., 2013). Pozzolans are fine-grained materials that react with lime when appended to the cement to create compounds that enhance the strength or other characteristics of the concrete or mortar (King, 2000). There are few available studies or pieces of literature on the use of sesame straw ash in concrete, but related literature on the use of agricultural waste ashes is reported. Research conducted on the suitability of sesame plant mucilage (SPM) as an admixture in the production of concrete by Orame et al., (2020) indicated that Sesame plant Mucilage (SPM) has a combined SiO2, Al2O3, and Fe2O3 composition of 25.58 %. However, the results of their studies showed that at 28 days of curing, concrete produced with different percentages of Sesame mucilage have higher compressive strength than the control mix with 33.2 N/mm2, 31.3 N/mm2, and 30.8 N/mm2 for 1.0 %, 1.5 %, and 2.0 % Sesame mucilage content respectively. Hakeem et al., (2022) reported that the addition of nano-sized sesame stalk ash (NSSA) and rice straw ash (RSA) increased the splitting tensile strength by 2 % and 5 % respectively. According to 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 the SSA mortar increased as the curing period increased. According to a study carried out on the effect of adding Sesame stalk fibre (SSF) to the concrete mixture by Elmardi et al., (2021) claimed that the strengths of SSF-concrete decreased as the percentage of sesame stalk fibre (SSF) increases, however, the addition of (SSF) increases the concrete resistance against crack growth. . According to Abubakar (2018) the optimum amount of RHA content to be used as a replacement of cement was around 10 % to 20 % with longer curing period, and beyond 20 % RHA there is an abrupt decrease in mechanical properties of concrete. Mounika et al., (2022) reported that the mechanical properties such as compressive strength, flexural strength and splitting tensile strength of concrete blended with RHA increase for smaller replacements by up to 30 %. Shaaban (2021) reported that the addition of CDP-RHA decreases the splitting tensile and flexural strength of concrete, whereas the tensile strength and flexural strength increase as the curing age increases. Ogork et al., (2015) reported that the compressive strength, splitting tensile strength and flexural strength of concrete decreased with an increase in GHA-RHA content. Ettu et al., (2021) reported that the flexural strength and tensile strength of the OPC-RHA-SDA composite concrete increased as the curing age increased and reduced as the percentage replacement of RHA-SDA content increased. Bashar et al., (2016) claimed that the use of palm oil fuel ash resulted in higher flexural and splitting tensile strength of geopolymer concrete, compared with the control sample. According to a study carried out by Bheel et al., (2021) the splitting tensile strength, compressive strength and flexural strength of concrete increased with the addition of up to 10 % MHA only, 30 % of WSA only, 15 % MHA and 30 % WSA together. Mohammed et al., (2021) claimed that the inclusion of millet husk ash (MHA) decreases the compressive strength, splitting tensile strength and flexural strength of self-compacting concrete (SCC) and 5 % MHA should be considered or used to produce grade 40 SCC. Ramasamy (2012) reported that concrete made with RHA was detected to be more resistant to hydrochloric (HCl) solution than the control specimen. He further stated that the addition of 20 % RHA indicated a high resistance against sulphuric acid attack for both cyclic and soaking. Saravana and Dhinakaran (2010) reported that adding 30 % NaCl led to a drop-off in the strengths of concrete, and chloride ion incursion as well as corrosion rate. Research conducted by Witkowska-Dobrev et al., (2021) disclosed that the strength of concrete under the influence of acetic acid declined by 22.23 % concerning the mean strength recorded beyond 28 days of curing, while in alkaline and neutral environments there was a drastic decrement in the strength by 44.27 % and 40.85 % respectively. A report by Mahmoodian and Alani (2017) claimed that specimens mass increased at the early levels of the corrosion process, and then decreased at the afterwards stages of the testing concerning the acidic solution used. However, they stated that the strength of the tested specimens did not change when the state of temperature changed, however, the increment in temperature has a hefty influence on the loss of weight of the concrete specimens that were lowered in the aggressive environment at 91 days. Umale and Joshi (2019) concluded that the influence of Hydrochloric (HCl) and Nitric acid on concrete is higher as equated to H2SO4 acid, and the complete submersion of the concrete specimens in 10 % HCl for 60 days led to a high decline in strength closed to 47 %, that is 45 % Nitric acid and 25 % H2SO4 acid. Purnomo et al., (2019) reported that the more citric acid solution is added the more hardened and sticky the concrete becomes, and the maximum strength of concrete was gotten at 0.15 % citric acid addition, with an increment in the strength by 82.2 % to the normal concrete. Sesame Straw is an agricultural waste that is normally dumped or burnt and sometimes left to decay and cause inconveniences to surroundings when not properly discarded. And these may produce a large quantity of waste that must be carried away and lay in sanitary landfills.

The study focused on investigating the influence of sesame straw ash (SSA) on the splitting tensile strength and durability 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 specific gravity of 3.16. The cement oxide composition is presented in Table 1. The fine aggregate used was sourced from Zaria Local Government Area, Kaduna State, Nigeria, with a silt content of 2 %, a specific gravity of 2.68, bulk density of 1737 kg/m^3. The coarse aggregate used has a specific gravity of 2.68 and a bulk density of 1425 kg/m^3. 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.

2.2 Methods

2.2.1 Tests on SSA-Cement Paste

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

2.2.2 Mix Proportions for SSA-Concrete

The design of the Experiment (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 of SSA-Concrete

Mix	Cement (kg/m^3)	SSA (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (kg/m^3)	W/C
T0	320	0	723	1231	176	0.55
T5	304	16	723	1231	176	0.55
T10	288	32	723	1231	176	0.55
T15	272	48	723	1231	176	0.55
T20	256	64	723	1231	176	0.55
T25	240	80	723	1231	176	0.55

2.2.3 Slump of Fresh Concrete

The workability test was performed on fresh concrete in line with BS 1881:102 (1983).

2.2.4 Splitting Tensile Strength of SSA-Concrete

The splitting tensile strength test on SSA-concrete prisms was conducted according to BS 1881-117: (1983). Prisms 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.

2.2.5 Water Absorption test of SSA-Concrete

The water absorption test was performed on SSA-concrete specimens in accordance with BS 812, Part 2, (1995). A total of eighteen (18) samples were cured for 28 days, and then after 28 days of curing, three (3) samples were tested for a mean.

2.2.6 Test of SSA-Concrete in Sulphuric Acid

The compressive strength test on SSA-concrete was conducted according to BS 1881-116: (1983). A total of fifty-four (54) concrete cubes were cured in a 5 % concentration of sulphuric acid (H_2SO_4) solution after 28 days of curing in water and three (3) samples were tested for a mean for each curing period (3, 7, and 28 days).

3. Results and Discussions

3.1 Oxide Composition of Cement and SSA

The results of the XRF test performed on cement, and SSA are displayed in Table 2. The oxide composition of SSA indicates that the total of iron oxide (Fe2O3), aluminium oxide (Al2O3) and silicon oxide (SiO2) is 28.92 % which is less than the lower limit of 70 % specified by ASTM C 618 for pozzolana. The CaO content of 45.42 % in SSA shows that it possesses some cementing properties, and is classified as a 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 in accordance with BS 882 (1992) for grading limits for fine aggregate. However, the coarse aggregate was well-graded. This proves that fine aggregate (sand) and coarse aggregate can be used in the production of concrete.

Table 2: Oxide Composition of Cement and SSA

Oxide	Cement (%)	SSA (%)
Na_2O	0.18	1.08
MgO	1.05	3.55
Al_2O_3	2.83	1.82
SiO_2	21.43	20.83
SO_3	1.42	2.52
K_2O	0.62	8.02
Ca	68.02	45.42
TiO_2	0.17	1.47
Cr_2O_3	-	0.01
Fe_2O_3	2.77	6.27
LOI	-	0.3

3.3 Slump of Fresh SSA-Concrete

The results of the slump test conducted on SSA-concrete are presented in Figure 2. It was observed that the slump of the concrete decreased as the percentage of SSA increased. The decrease may be a result of the high surface area of SSA for constant water content (Wazumtu and Ogork, 2015**).** It may also be accredited to the density of the SSA which is less than that of cement and particle size fineness. Similar behaviour was reported by (Sulaiman & Aliyu, 2020).

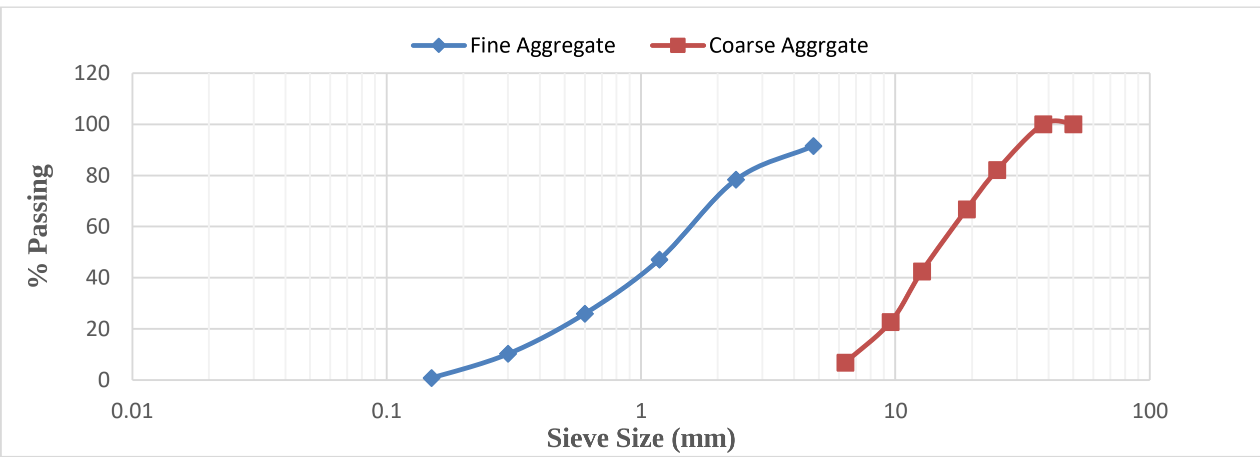

Figure 1: Particle Size Distribution of Fine Aggregate and Coarse Aggregate

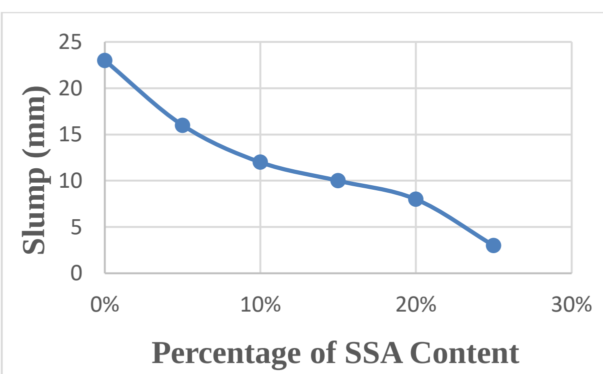

Figure 2: Relationship between Slump and percentage of SSA Content

3.4 Splitting Tensile Strength of SSA-Concrete

The results of splitting tensile strength of concrete produced with various percentages of SSA are presented in Figure 3. The splitting tensile strength of SSA-concrete decreased as the percentage of SSA increased. It increased as the curing age increased. The decrease in splitting tensile strength of SSA-concrete most likely owing to the increase in the pozzolanic chemical reaction of silica from SSA and liberated calcium hydroxide as a by-product of cement hydration making excess calcium-silicate-hydrate where the binder efficiency increased, consistent with Ettu *et al.*, (2016). Similar behaviour was discovered by Ettu *et al.*, (2021).

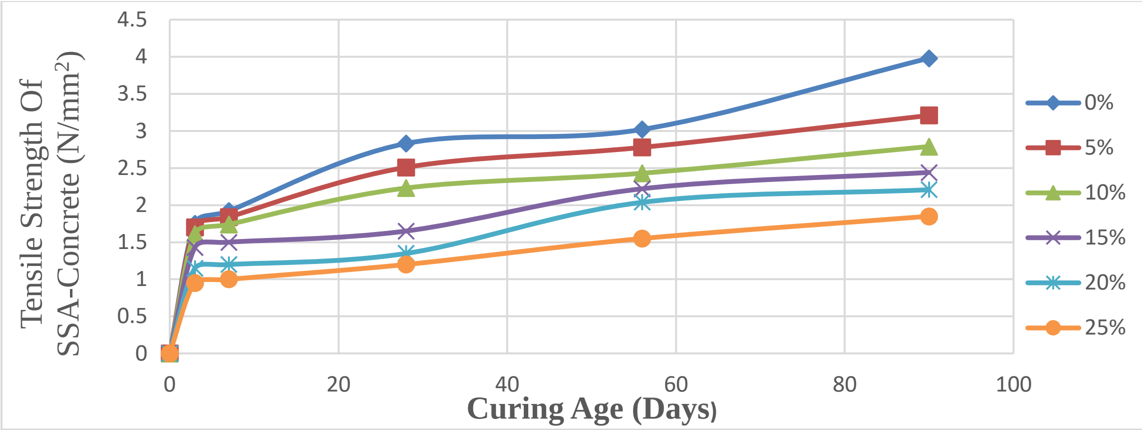

Figure 3: Relationship between Tensile Strength and Curing Age

3.5 Compressive strength of SSA-Concrete after immersion in 5 % Conc. of H_2SO_4

The results of the compressive strength of SSA-concrete cured in a 5 % concentration of H_2SO_4 were presented in Figure 4. It was discovered that the compressive strength of SSA-concrete decreased as the percentage of SSA content and the curing age increased. It happened that all the values of compressive strength were lower than the control at all replacement levels. However, it was found that at 3 days of curing, the strength of concrete produced with 5 % SSA was 21.73 N/mm^2 which exceeded the target strength of 20 N/mm^2. So, the decrease in compressive strength of SSA-concretes indicates the amount of weight loss by concrete and led to its dissolution because of the H_2SO_4 attack. The loss of weight of concrete specimens in 5 % concentration of H_2SO_4 solution was because of ettringite formation. H_2SO_4 attacks $Ca(OH)_2$ and form $CaSO_4$ that is stripped out of concrete. The reaction of calcium silicate hydrate (C-S-H) with H_2SO_4 forms frail silica gel that is easily destructed by outside physical forces. So, the formation of (ettringite) leads to expansion, loss of weight, cracking and dissolution of concrete, consistent with (Kumar and Baraik 2016). Additionally, Table 3 shows the compressive strength of concrete treated and untreated with acid at 28 days of curing.

Table 3. Compressive Strength of concrete

	Compressive Strength at 28 days of curing in water (N/mm^2)	Compressive Strength at 28 days of curing in H_2SO_4 after 28 days in water (N/mm^2)	Percentage difference (%)
0%	24.53	15.53	36.69
5%	22.83	14.87	34.87
10%	20.20	12.33	38.96
15%	16.83	9.00	46.52
20%	11.37	8.10	28.76
25%	9.67	5.13	46.94

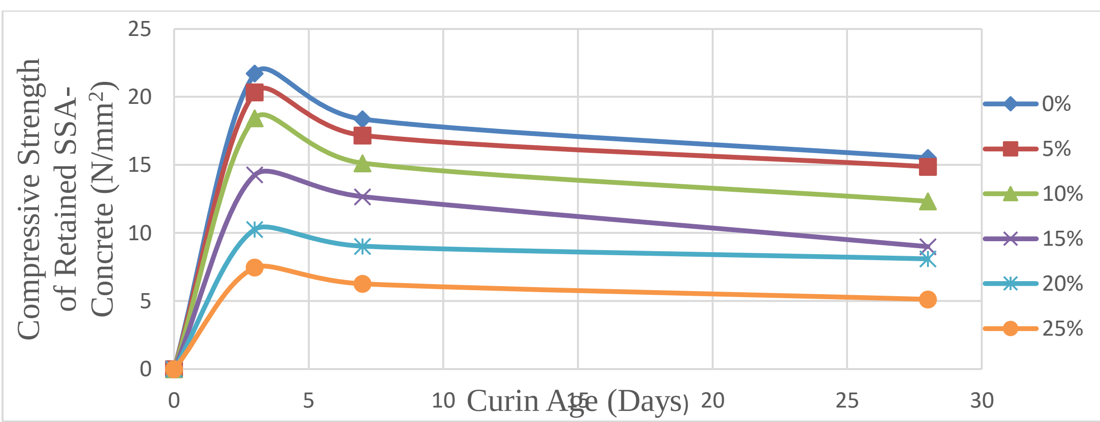

Figure 4: Relationship between Compressive Strength of Retained SSA-Concrete and Curing Age

3.6 Water Absorption of SSA-Concrete

The results of the water absorption test carried out on SSA-concrete are presented in Figure 5. It was observed that as the quantity of SSA content increased amount of water absorbed increased. The increase in water absorption may be the result of adding SSA content. It shows that SSA-concrete absorbed more water than the normal concrete.

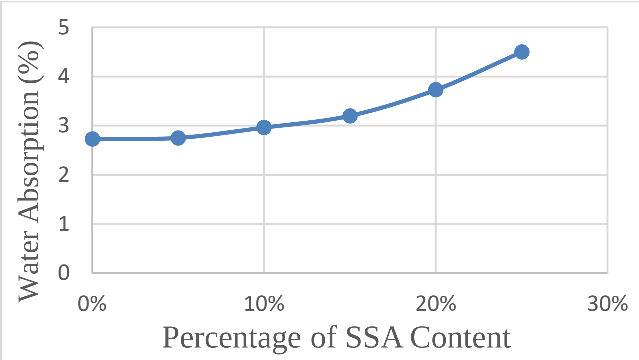

Figure 5: Relationship between water absorption and the percentage of SSA Content

3.7 Density of SSA-Concrete cured in H_2SO_4 Solution

The densities of concrete produced with different percentages of SSA as a partial replacement of cement are presented in Figure 6. It shows that the densities of SSA-concrete decreased as the curing age increased. The decrease in the density of concrete may be due to an acid attack, which led to the deterioration of concrete. It was observed that most of the densities fall within the limits of 2200 kg/m^3 to 2600 kg/m^3. Moreover, the densities of concrete treated and untreated with acid are presented in Table 4. It shows that the percentage difference increased as the percentage addition of SSA content increased.

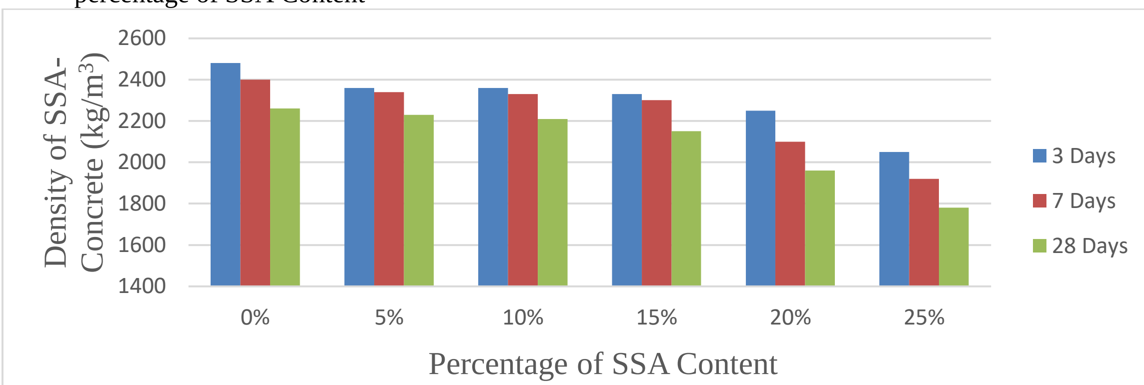

Figure 6: Relationship between density of concrete and percentage of SSA Content

Table 4. Density of SSA-concrete

	Density of Concrete at 28 days of curing in water (kg/m^3)	Density of Concrete at 28 days of curing in H_2SO_4 after 28 days in water (kg/m^3)	Percentage difference (%)
0%	2460	2260	8.13
5%	2446	2230	8.83
10%	2460	2210	10.16
15%	2440	2150	11.89
20%	2430	1960	19.34
25%	2430	1780	26.75

4. Conclusions

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

i. The addition of SSA content decreases the workability of fresh SSA-concrete but increases water absorption of SSA-concrete.

ii. The splitting tensile of SSA-concrete increases as the curing age increases but decreases as the percentage of SSA content increases.

iii. The compressive strength of SSA-concrete decreased as the percentage of SSA content and curing age in 5 % concentration of H_2SO_4 solution increased.

iv. It is concluded that SSA could be used as a partial replacement for cement in concrete

References

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

Bakar, B. H. A, Putrajaya, R. C, and Abdulaziz, H. (2010). Malaysian Saw dust ash – Improving the Durability and Corrosion Resistance of Concrete: Pre-review," Concrete Research Letters, vol. 1 No. 1, pp. 6-13.

Bashar, I. I., Alengaram, U. J., Jumaat, M. Z., Islam, A., Santhi, H., Sharmi, A. (2016). Engineering Properties and Fracture Behaviour of High Volume Palm Oil Fuel Ash Based Fibre Reinforced Geopolymer Concrete. *Construction and Building Materials*. Vol. 111, pp: 286-297. https://doi.org/10.1016/j.conbuildmat.2016.02.022.

Bheel, N., Ali, M. O. A., Kirgiz, M. S., Galdino, A. G. D., Kumar, A. (2021). Fresh and Mechanical Properties of concrete made of Binary Substitution of Millet Husk Ash and Wheat Straw Ash for Cement and Fine Aggregate. *Journal of Materials Research and Technology*, Vol. 13, pp: 872-893. https://doi.org/10.1016/j.jmrt2021.04.095.

BS 812, Part 2, (1995). Method for Determination of Water Absorption, British Standard Institution, London,

BS 882, Part 2, (1992). Grading limits for fine aggregates, 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.

BS EN 196, Part 3, (1995). Methods of testing cement: Determination of setting time and soundness. 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 and Building Engineering.* Vol.3 No.1, Pp: 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.

Ettu, L. O., Anyaogu, L., and Diboyesuku, I.D. (2021). Investigation of the Tensile and Flexural Strengths of Concrete Containing Rice Husk and Saw Dust Ashes. *International Journal of Scientific & Engineering Research*, Vol. 12, No. 7, pp: 1183-1188.

Hakeem, I. Y., Amin, M., Zeyad, A. M., Tayeh, B. S., Maglad, A. M., Agwa, I. S. (2022). Effects of Nano Sized Sesame Stalk and Rice Straw Ashes on High-Strength Concrete Properties. *Journal of Cleaner Production*, 370. https://doi.org/10.1016/j.jclepro.2022.133542.

King, B. (2000). A Brief Introduction to Pozzolans in: Alternative Construction – Contemporary Natural Building Materials, John Wiley and Sons, London.

Mahmoodian, M and Alani, A. M, (2017). *Effect of Temperature and Acidity of Sulfuric Acid on Concret Properties. Journal of Materials in Civil Engineering, Vol. 29, No. 10.*

Mohammed, A., Aboshio, A., Aliyu, M. M (2021). Performance of Millet Husk Ash in Self-Compacting Concrete. *Nigerian Journal of Technology (NIJOTECH),* Vol. 40, No. 6, pp: 1010-1017. https://dx.doi.org/10.4314/njt.v40i6.3

Mounika, G., Baskar, R., Rama, J. S. K. (2022). Rice Husk Ash as Potential Supplementing Cementitious Material in Concrete Solution towards Sustainable Construction. *Innovative Infrastructure Solution*, Vol. 7, No. 1, pp: 1-14. https://doi.org/10.1007/s41062-021-00643

Munshi, S., Dey, G., Sharma, R. P. (2013). Use of Rice Straw Ash as Pozzolanic Material in Cement Mortar. IACSIT International Journal of Engineering and Technology, vol. 5, No. 5, pp: 603-606.

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

Ogork, E. N. and Uche, O. A. (2014). Effects of Groundnut Husk Ash (GHA) in Cement Paste and Mortar. *International Journal of Civil Engineering and Technology (IJCIET)*, Vol. 5, No. 10, pp: 88-95. www.jifactor.com

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

Oriola, F. O., Moses, G. and Afolayan, J. O. (2015). Effect of Combining Metakaolin and Cement kiln Dust as Cement Replacement in Concrete. *Academy Journal of Science and Engineering*, Vol. 9, No. 1, Pp: 101-111.

Purnomo, J., Sumarni, S. and Saputro, I. N. (2019). Effect of Citric Acid on Setting Time and Compressive Strength of Concrete. IOP Conference Series: Materials Science and Engineering, Vol. 578, pp: 1 – 8. https://doi:10.1088/1757-899X/578/1/012077.

Ramasamy, V. (2012). Compressive Strength and Durability Properties of Rice Husk Ash Concrete. KSCE Journal of Civil Engineering, Vol. 16, No. 1, pp: 93 – 102. DOI 10.1007/s12205-012-0779-2.

Saravana, K. P. and Dhinakaran, G. (2010). Effect of Water on Strength, Durability and Corrosion of Concrete. *Journal of Civil Engineering Research and Practice*, Vol. 7. No. 2. DOI:10.4314/jcerp.v7i2.63724.

Shaaban, M. (2021). Properties of Concrete with Binary Binder System of Calcined Dolomite Powder and Rice Husk Ash. *Heliyon*, Vol. 7, No. 2, pp: 1-6. https://doi.org/10.1016/j.heliyon.2021.e06311

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.

Umale, S. and Joshi, G. V. (2019). Study of Effect of Chemicals (Acid) Attack on Strength and Durability of Hardened Concrete. *International Research Journal of Engineering and Technology (IRJET)*, Vol. 6, No. 4, pp: 548 – 552.

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

Witkowska-Dobrev, J., Szlachetka, O., Dohojda, M., Wisniewski, K. (2021). Effect of Acetic Acid on Compressive Strength and Geometric Texture of the Surface of C20/25 Class Concrete. *Sustainability*, Vol. 13, pp: 1 – 16. https://doi.org/10.3390/su13095136