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Effect of Partial Replacement of Cement with Banana Stem Ash on Compressive and Splitting Tensile Strengths on Concrete

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Abstract: *The price of cement (the binding ingredient in concrete) is increasing in the developing world because of inflation. Since concrete in itself is the most used materials in the world because of some of its properties like fire resistance and toughness, therefore, the more the production of concrete, the more the need for cement. As a result, there is the need to reduce the quantity of cement used. Banana stem, which is an agricultural waste, can be used as a partial replacement for cement. In this research, banana stem was dried and burned at 600ºC to obtain banana stem ash. A total of seventy-two 150 mm × 150 mm ×150 mm concrete cubes and seventy-two cylindrical concrete of 100 mm diameter and 200 mm height were cast in order to determine their compressive strength and splitting tensile strength respectively using percentages of banana stem ash of 2.5%, 5%, and 7.5% to replace cement in the water curing period of 7, 14 and 28 days. It was observed that 2.5% replacement of cement with banana stem ash showed the maximum value for both compressive strength and spilt tensile strength.*

Key Word*: Concrete, Pozzolans, compressive strength, split tensile strength*

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I. Introduction

Concrete is composed of aggregates (fine and coarse), cement, water and sometimes admixture. The aggregates are the inert materials, cement is the binding agent and water provides the hydrating medium [1]. Due to the various advantages of using concrete as construction materials, it becomes the most used constructional materials in the world ([2], [3], [4]). However, the disadvantages of concrete, such as low tensile strength, low ductility and susceptibility to cracking when in service make researchers looked for how to improve some of its properties. Natural fibers are used as an addictive or to replace some of the production materials [5]. The addition of natural fibers to the concrete can enhance the engineering properties such as fracture, toughness, tensile strength, flexural strength, compressive strength and other performance of the concrete [6]. Therefore, the cement in the concrete can be replaced with other materials in order to improve its properties. One of such materials is pozzolans. As noted by [7], [8], and [9], pozzolans are siliceous material, which by itself possesses no cementitious properties but in the processed form or finely divided form, react in the presence of water with lime, to form compounds of low solubility having cementitious properties. These pozzolans may either be natural or artificial. The natural ones are volcanic ashes, pumices, tuffs, calcined diatomaceous earths, opaline, cherts, clay and shales which are natural pozzolans. The reactive chemical compositions of natural pozzolans are silica (SiO_2), alumina (Al_2O_3), and iron oxide (Fe_2O_3). The sum of these three oxides is required to a minimum value of 70% by mass for a suitable pozzolan ([10], [11], [12). Examples of the artificial ones are banana fiber ash, Fly ash (FA) or pulverized fuel ash (PFA), silica fume, slag, burned clay and shale (including some brick), moler (burned diatomaceous earth) and rice husk ash [13]. Banana and plantain which are agricultural plants, are trees that are very common in the western part of Nigeria and after harvesting their fruits, their stems and leaves become wastes. These wastes can be utilized immensely as pozzolans so that cement consumptions during construction can be minimized. [14] studied the mixture in percentages of coconut fiber and banana fiber as partial replacement of cement in production of concrete. They realized that there was improvement in compression and tensile strength of the concrete and also the resistance to cracking and spalling is enhanced. [15] conducted a study on the banana fiber reinforced concrete. They mixed banana peel with its leaf with different grades of concrete and discovered that they produced concrete with good tensile strength and with an amount of cement used decreased. Similarly, [16] investigated the effects of banana fibers as reinforcement material on hardened properties of concrete. It was discovered that the tensile strength increased and that the use of banana fiber replacement will prove to be an environmentally and economically friendly solution. As a result of the researches conducted so far on banana fiber as a partial replacement of cement in the production of concrete, therefore, this research focuses on replacing cement with banana stem ash in different percentages for grades 20 and 24 concrete cubes and cylinder in order to determine their effects on compressive strength and tensile strength.

II. Experimental Investigation

The materials used for this investigation were Ordinary Portland cement, aggregates (fine and coarse), water and pozzolans (Banana stem ash). All the materials were obtained locally. Banana stem ash (BSA) was obtained from burning of banana stem from different banana plantation in Akure, Ondo State of Nigeria. After obtaining the banana stems, they were cut in piece to increase their surface areas, sun dried and processed through burning in a furnace for 2 hours at a temperature of 600℃. The residues were allowed to cool for 72 hours and then collected for sieving. The fine particles were sieved through a sieve of 75 µm aperture size to obtain fineness like that of the Portland cement used.

The chemical composition of the banana stem ash was obtained using X-Ray fluorescence (XRF) as shown in Table 1.

Table 1: Chemical Composition of the Banana Stem Ash

Constituent	Concentration (%)
SiO_2	16.600
Al_2O_3	2.400
Fe_2O_3	1.300
MgO	0.000
CaO	57.400
TiO_2	0.500
Na_2O	0.000
K_2O	13.500
V_2O_5	0.016
MnO	0.500
CuO	0.500
P_2O_5	0.500
K_2O	13.500
SrO	0.150
SO_3	0.741

2.1 Batching

The sample was batched by weight, but the replacement of the cement was done by volumes. The schedules of materials are as presented in Tables 2 and 3

Table 2: Schedule of Material for Grade 20 Concrete

Percentage Replaced	Cement (kg)	Sand (kg)	Granite (kg)	Water/cement ratio	Pozzolan (m^3)
0%	101	202	404	0.65	0.0000
2.5%	98.9	202	404	0.65	0.0018
5%	95.9	202	404	0.65	0.0035
7.5%	93.4	202	404	0.65	0.0053

Table 3: Schedule of Material for Grade 25 Concrete

Percentage Replaced	Cement (kg)	Sand (kg)	Granite (kg)	Water/cement ratio	Pozzolan (m^3)
0%	127	191	382	0.55	0
2.5%	123	191	382	0.55	0.0022
5%	120.6	191	382	0.55	0.0044
7.5%	117.5	191	383	0.55	0.0066

2.2 Casting of concrete specimens

The cylinder concrete and the concrete cubes were cast for both grades 20 and 25 using the water-cement ratio of 0.65 and 0.55 respectively. 144 number of specimens were cast, 72 concrete cubes of sizes 150 mm × 150 mm× 150 mm in total were cast for 0 %, 2.5 %, 5 % and 7.5 % for 7 ,14, and 28 days and same was done for cylindrical concrete of size 200 mm height and 100 mm diameter as shown in Figures 1 and 2. The specimens were cured in water.

Figure 1:Cube Specimen Casted

Figure 2: Cylinder Specimen Casted

2.3 Testing of cured specimens

The concrete cubes were tested for their compressive strength using universal testing machine (Figure 3) for curing period of 7, 14 and 28 days. Also, the cylindrical concrete specimens were tested with compression machine for their split tensile strength for the same curing period as shown in Figure 4. These tests were done at the Concrete Laboratory FUTA of the Federal University of Technology, Akure, Ondo state Nigeria.

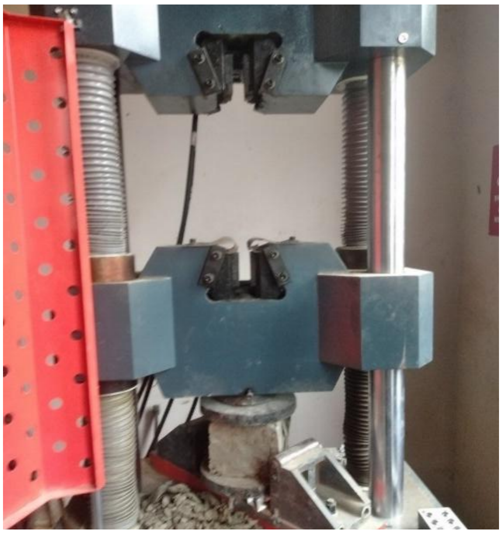

Figure 3: Compressive Strength test

Figure 4: Compression machine for tensile strength test

III. Result and Discussions

The compressive strength of concrete helps to know the strength and the quality of the concrete i.e., the magnitude of the extent of the capability of the concrete to resist load is know in advance. Figures 5 and 6 show the plot of the compressive or cube strength of the concrete cubes against the curing days with various percentages of the BSA in the replacement of the cement for grades 20 and 25 respectively. It could be observed that their compressive strength increases for each curing days. Similarly, the percentage replacement of 2.5% BSA shows the highest strength for both grades of the concrete and 7.5% replacement shows the lowest strength. However, for the splitting tensile strength, the same pattern was observed as 2.5% replacement of BSA shows the highest strength as seen in Figures 7 and 8. This shows that at 2.5% replacement of cement with BSA, appreciable strength can be achieved that will reduce agricultural waste, banana plant being eco-friendly, and also reduces land pollution.

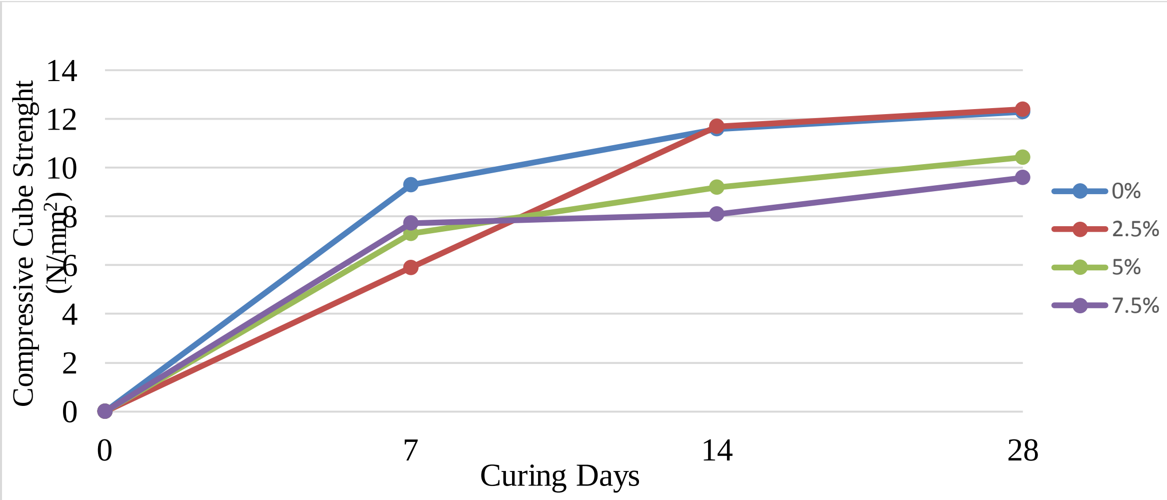

Figure 5: Graph of compressive cube strength against curing days for Grade 20 concrete

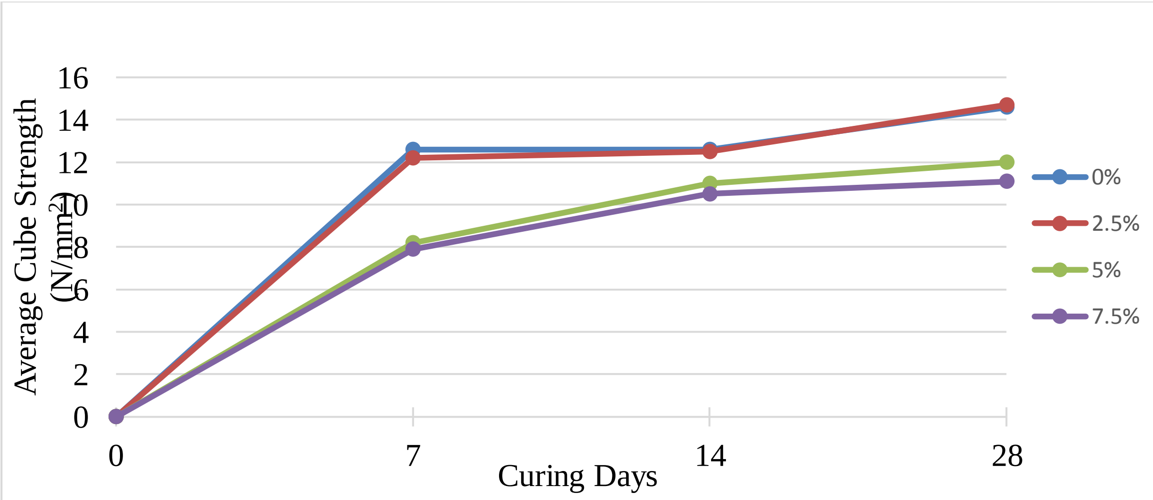

Figure 6: Graph of Compressive Cube Strength Against Curing Days for Grade 25 concrete

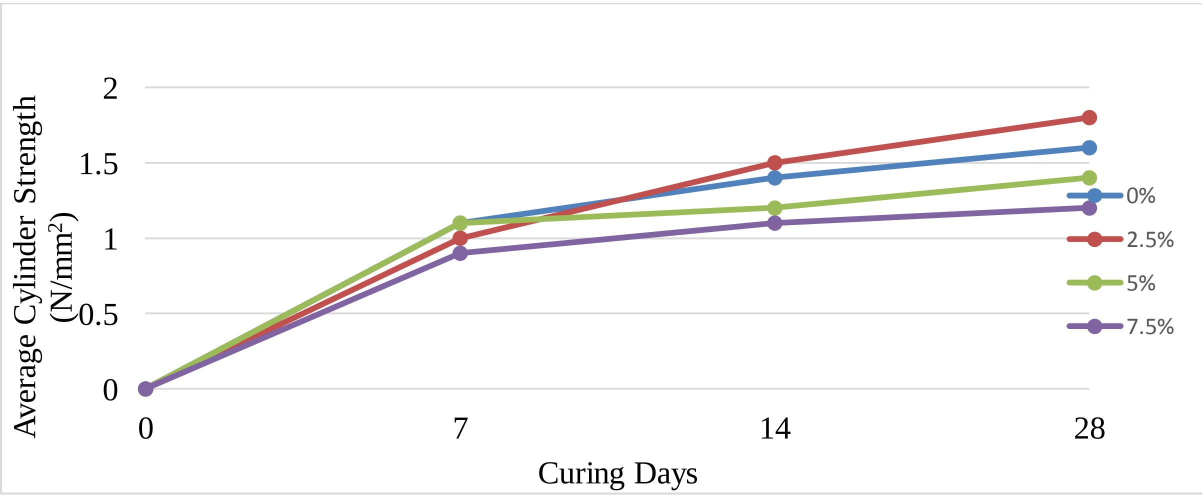

Figure 7: Graph of split tensile strength against curing days for grade 20

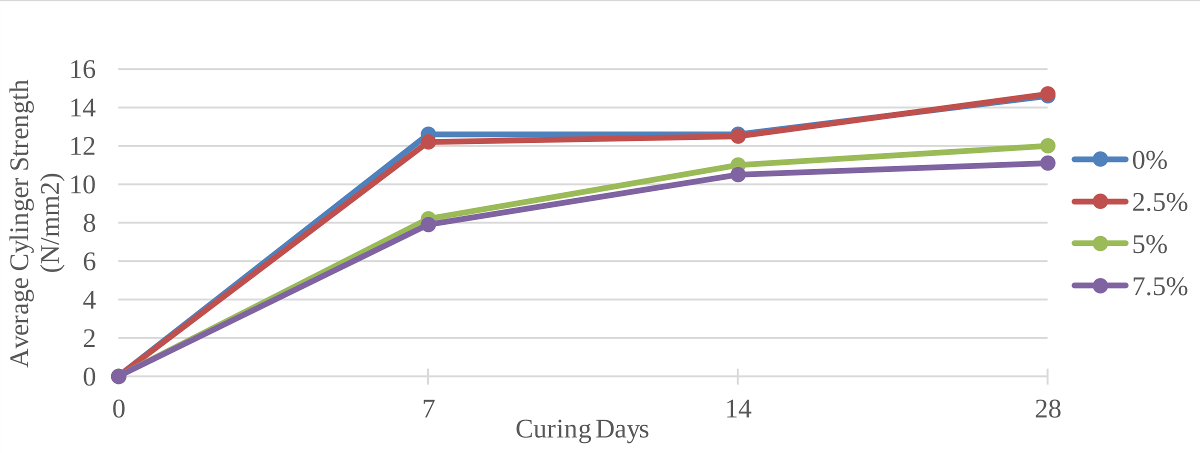

Figure 8: Graph of split tensile strength against curing days for grade 25

The effect of partial replacement of cement with BSA on compressive strength (Table 4) and splitting tensile strength (Table 5) was analysed using Analysis of Variance test (ANOVA). In Tables 4 and 5, the LSD Post Hoc Test for the use of BSA as partial replacement for cement shows that there was no significant difference in the change that took place for all the percentage replacements. The implies that the use of BSA in concrete will affect both the compressive and the tensile strength but the best strength obtained is for 2.5% replacement as seen in the mean plot in Figure 9.

Table 4: LSD test for compressive strength of concrete made from Banana stem ash (BSA) as a partial replacement for cement for 7 days, 14 days and 28 days curing. 1- OPC (control), 2 – BSA (2.5%), 3 - BSA (5%) and 4 - BSA (7.5%)

i	j	MD (i – j)	P	Remarks
1	2	1.06667	.562	NS
	3	2.09000	.270	NS
	4	2.59000	.180	NS
2	3	1.02333	.578	NS
	4	1.52333	.413	NS
3	4	0.50000	0.784	NS

*Mean Difference (MD) is significant at $\alpha_{0.5}$, NS = Not significant

Table 5: LSD test for splitting tensile strength of concrete made from Banana stem ash (BSA) as a partial replacement for cement for 7 days, 14 days and 28 days curing. 1- OPC (control), 2 – BSA (2.5%), 3 - BSA (5%) and 4 - BSA (7.5%)

i	j	MD (i – j)	P	Remarks
1	2	-0.6667	.763	NS
	3	.133333	.550	NS
	4	.30000	.197	NS
2	3	.200000	.376	NS
	4	.36667	.124	NS
3	4	-.1.6667	0.457	NS

*Mean Difference (MD) is significant at $\alpha_{0.5}$, NS = Not significant

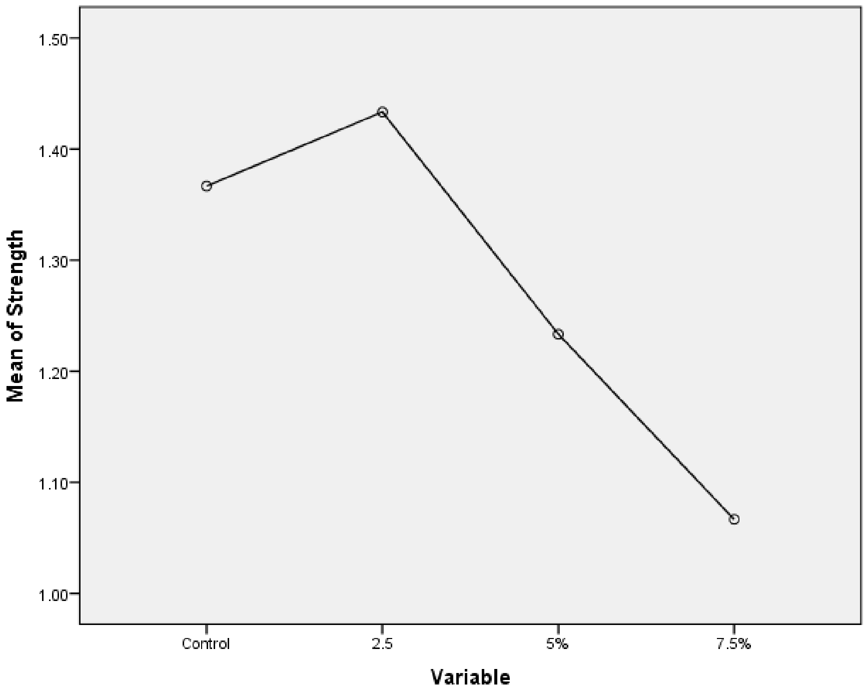

Figure 9: Mean plot of splitting tensile strength against percentage replacement for grade 20

IV. Conclusions

This research investigates the partial replacement of cement with banana stem ash. From this study, the following can be deduced:

i. There is no significant change in the weight of the BSA and the Portland cement used.
ii. From the concrete samples, only 2.5% replacement meet the strength of the control samples with respect to compressive and splitting tensile strength of the concrete.
iii. The concrete samples with BSA of 5% and 7.5% replacements did not meet the strength of the control samples with respect to the compressive and tensile strength of the concrete.
iv. The concrete sample with the BSA replacement of 2.5% has the highest optimal compressive and tensile strength.

References

[1]. Neelam, S. (2020). Reinforced Cement Concrete Design. S. K. Kataria and Sons, India.

[2]. Oyedepo, O. J., Olanitori, L. M. and Akande, S. P. (2015). Performance of coconut shell ash and palm kernel shell ash as partial replacement for cement in concrete. Journal of Building Materials and Structures, 2(1), 18–24.

[3]. Jugal, R. P. and Aman, S. K. (2018). Experimental Investigation on Properties of Concrete by Partial Replacement of Cement with Banana Leave Ash., 6th International Conference on Recent Trends in Engineering and Technology.

[4]. Akingbonmire, S. L. and Ikumapayi, C. M. (2019). Appraisal of different production methods on coarse aggregate performance in concrete, International Journal of World Policy and Developmental Studies, 4(3), 20 – 29.

[5]. Karim, N. A. (2014). Strength Performance of Banana Fiber Ash as Cementitious Materials with Different Temperature. Malaysia: Faculty of Civil Engineering and Earth Resources University Malaysia Pahang.

[6]. Mostafa, M. and Uddin, N. (2016). Experimental Analysis of Compressed Earth Block (CEB) with Banana Fibers Resisting Flexural and Compression Forces. Case Studies in Construction Materials, 5, 53-56.

[7]. Oluremi, A. A., 1990. Input of local materials in buildings as a means of reducing cost of construction. Journal of the Nigerian Institute of Quantity Surveyors, pp. 12-14.

[8]. Ikumapayi, C. M. and Akingbonmire, S. L. (2018). Effects of Bamboo Leaf and Locust Beans Pod Ashes on Autogenous shrinkage Strain and Compressive Strength of Mortar. Journal of Engineering and Engineering Technology, 12(1), 36 – 41.

[9]. Ikumapayi, C. M., Akingbonmire, S. L. and Oni, O. (2019). The Influence of partial Replacement of Some Selected Pozzolans on the Drying Shrinkage of Concrete. Scientific Review, 5(11), 189 – 197.

[10]. Ghassan, K. A. and Mouin, A. (2013). Natural Pozzolan as a Partial Substitute for Cement in Concrete. The Open Construction and Building Technology Journal, 7, 33 - 42

[11]. Pontes, J., Silva, A. S. and Faria, P. (2013). Evaluation of Pozzolanic Reactivity of Artificial Pozzolans. Materials Science Forum, Vols. 730 – 732, pp 433 - 438.

[12]. ScienceDirect (2022). Natural Pozzolans. Available at https://www.sciencedirect.com/topics/engineering/natural-pozzolans. Accessed 5th May, 2022.

[13]. Odeyemi, S. O., Ibitoye, B. A. Abdulwahab, R. and Sholagberu (2020). Review of selected Pozzolanas for Concrete Production. LAUTECH Journal of Engineering and Technology, 14 (2), 10 – 24.

[14]. Raphael, C., Hema, S. and Vadivel, M. (2016). Experimental Studies on Coconut Fibre and Banana Fibre Reinforced Concrete. International Journal of Earth Sciences and Engineering, 9 (3), 529 – 533

[15]. Tirkey, N. and Ramesh, G. B. (2018). Experimental Study on the Banana Fiber Reinforced Concrete. International Journal of Pure and Applied Mathematics, 119 (18), 2053 – 2056.

[16]. Khaskheli, A. A., Memon, F. A., Tunio, A. H., Abro, N. A., and Tunio, M. H. (2020). Effect of Banana Fibers as a Reinforcement Material on Hardened Properties of Concrete. International Research Journal of Modernization in Engineering Technology and Science, 4 (1), 787 – 791.

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