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Investigation of Pozzolanic Action of Biomass Ash from Clean Sawdust on Sandcrete Block

[1]Nwachukwu, A. N., [2]Ibearugbulem, O. M., [3]Njoku, K. O., [4]Amasiatu, O.S., [5]Israel, V.F.

[1,2,3,4,5]*Department of Civil Engineering, Federal University of Technology, Owerri, Nigeria*

---***ABSTRACT***---

This paper presents the investigation of pozzolanic action of ash from clean sawdust biomass. Sawdust biomass was obtained from timber market Owerri. It was cleaned by removing the earth and other impurities. After cleaning the biomass, it was incinerated to ashes inside a clean metallic drum. The ash deposit was collected and sieved using 425 microns sieve to remove coal and unburnt sawdust particles. When this was done, the ash was subjected to physical and chemical tests. Sandcrete blocks were made using sand, cement, water and the ash obtained herein. The ash was used to replace the cement at 5%, 10%, 15%, 20% and 25% levels. A constant water-cement ratio (by mass) of 0.6 was used. Three hollow blocks of 450 x 225 x 225 mm was molded for each mix ratio. The produced sandcrete blocks were cured for 3, 7, 14, 21, 28, 56 and 90 days. Curing was achieved by covering the blocks with a cloth (something like blanket), which was kept moist throughout the curing period.After curing the blocks were allowed to surface dry and tested for saturated surface dry (SSD) density and compressive strength in conformity with BS 1881: Part 115 (1986). From the obtained results, the specific gravity, loose bulk density (kg/m3) and fineness modulus are 2.15, 815 and 1.85 respectively. The pozzolanic oxides composition are 0.47, 0.23 and 0.23 for SiO2, Al2O3 and Fe2O3 respectively with CaO having the highest composition of 51.78 and loss on ignition of 16. Other major oxide compositions are 12.72 and 9.23 for K2O and MgO respectively. Compressive strength of sandcrete blocks increases linearly with increase in cement content and with increase in saturated surface dry density. It reduces linearly with increase in ash from clean sawdust biomass. The compressive strength also increases parabolic with curing age and this increase appears to flatten as curing age reaches 90 days and more. For all curing ages, the compressive strength is highest for sandcrete blocks with zero percent replacement with the ash from clean sawdust biomass. The percentage increases in compressive strength when compared with 7 days compressive strength are 16.67%, 24.24%, 43.95, 54.55% and 57.62% for the ages of 21 days, 28 days, 56 days and 90 days respectively. The highest recorded compressive strength is 2.95 MPa from 90 days of curing and zero percent replacement of cement.

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I. INTRODUCTION

The major source of silicon to wood is the bark and natural holes in the trunk. Termites and other organisms carry soil mineral from the earth to the wood through the bark and these holes. Soil can also contaminate wood during harvest (Kofman, 2012).According to him, wood ash is composed of macronutrient, micronutrient and some heavy metals the tree took during its lifetime. These are phosphorus, potassium, calcium and magnesium, iron, sodium, manganese and copper, zinc, lead, cobalt and cadmium. Other nutrients taking up by tree but vented in the flue gasses during ashing include sulphur and nitrogen. The pH of wood ash is about 12. Ash content of the wood depends on the mineral it deposits after combustion. This generally will be high when the wood is contaminated with soil before combustion. Wood ashes with high silica content due to contamination with soil are predominant obtained from Hogfue (wood that has been crushed with a blunt instrument, unlike wood chip, that has been cut with sharp tools) from garden waste, stumps and roots. Bark of wood,Herbaceous wood,stumps and root(Kofman, 2012,Pitman, 2012 and Kang et al., 2014). The implication of this is that pure wood does not have silicon. Hence, any silica content of wood is due to secondary introduction (impurity or contamination). Calcium is the major mineral element in wood ash (Muse and Mitchell, 1995, Hakkila, 1989, Campbell, 1990 and Zajac, 2018). On Table 2 of Pitman (2012) the summation of the major elements (Calcium + Potassium + Magnesium) is more than 65% of the dry mass of the wood ash for different types of wood (both Conifers and Broadleaves).Misra et al. (1993) is in agreement with Pitman. According to them the major constituents of wood ash are calcium, potassium and magnesium and the very minor constituents (seen in traces) include iron, aluminum, copper, zinc, sodium, silicon and boron. However, manganese, sulfur and phosphorous are present in the neighborhood of 1% (See their Table 4).In another work, Fusadeet al. (2019)

the composition of wood ash as percentage of dry mass include: CaO = 49, K2O = 25.8, SiO2 = 9.34, MnO = 3.43, P2O5 = 3.29, MgO= 2.66, Fe2O3 = 1.98, Al2O3 = 1.18 and SO3 = 1.02. The wood ash they used was obtained from biomass boiler (West Dean, UK). High content of silica is explained because the wood used in the boiler are usually not washed to remove soil impurities before usage. Furthermore, Ban and Ramli(2011) in their work titled "Properties of high calcium wood ash and densified silica fume blended cement" tried obtaining the chemical composition of biomass from local rubber tree (Heveabrasiliensis). Result showed high calcium content after incineration of the wood at a temperature of about 8000C in Bio-Turbomax boiler. Some of the results obtained by them include:CaO = 61, K2O = 12, SiO2 = 2.7, MnO = 0.86, P2O5 = 2.7, MgO = 8.7 , Fe2O3 = 1.3, Al2O3 = 1.3 and SO3 = 2.8, Cl= 0.1. TiO2 = 0.11, ZnO = 0.1, SrO = 0.22, CuO = 0.014, Rb2O = 0.052, C = 6.7, specific surface (m2/g) = 0.611, Loss on ignition (%) = 18, Media particle diameter, d50 (μm) = 8.39. From the result it is seen that silica is 2.7 and it may be as a result soil impurity in the rubber wood timber.

However, there are several reported works on wood ash, sawdust ash, biomass ash, waste wood ash etc. with high silica content (Elinwa and Mahmood, 2002, Udoeyo and Dashibil, 2002, Elinwa and Ejeh, 2004,Udoeyo et al., 2006, Wang et al., 2008andVassilev et al., 2010). Silica (SiO2), Alumina (Al2O3) and Ferrite (Fe2O3) are the mineral components that indicate pozzolanic activity of ashes. A pozzolan is a material that is not cementitious on its own, but in in finely divided form and in the presence of water reacts with calcium hydroxide to form cementitious material. ASTM C 618 (1994) specified the summation of silica, alumina and ferrite to be up to 70% for the material to be regarded as pozzolan. However, the presence of these oxides, even when their summation is less than 70%, in ashes makes the ashes exhibit some pozzolanic behaviors.Pozzolanic behavior is addition of further strength to concrete (or sandcrete or any other crete {crete means mixture of water, cement and aggregate}) after 28 days of curing occasioned by reactions between the three oxides (silica, alumina and ferrite, hereinafter called pozzolanic oxides) and the released calcium hydroxide from cement hydration. If the amount of pozzolanic oxides is less than 70%, lesser additional strength is added to the crete. On the other hand, more strength is added to the crete when the amount of pozzolanic oxides is up to 70% and more. More so, the absence of pozzolanic oxides or very small amount of the oxides in the ashes used to partially replace cement in a crete will only result to reduction in the strength of crete.

Water-cement ratio to be used for sandcrete block is such that the block will be moldable. The sample is adjudged moldable when molded (caked) by pressing in the palm without dripping (draining) off water (Raheem, 2006). Going by earlier works, the water-cement ratio that makes a sample moldable is about one-tenth of sand proportion (Ezeh et al., 2010, Ezeh and Ibearugbulem 2010 and Afolayan, 2017).The allowable water absorption rate for sandcrete block recommended by NIS 87 (2000) is 12.0%. When this limit is exceeded, the durability of the block is not guaranteed.

II. MATERIALS AND METHODS

Sawdust used in this work was obtained from Owerri Timber Market Naze (popularly known as Ogbosisi). Care was taken to avoid collecting it along with sand and other deleterious matters. It was thoroughly washed to remove every trace of sand and clay that contaminated the tree (and log) before processing it into timbers.The sample was placed in a clean metallic drum with no cover and burnt until it reduces to ash. Ash obtained was sieved with 425 microns sieve to remove coal and unburnt sawdust. It was subjected to both physical and chemical composition tests.In conducting the chemical composition test, X-Ray Fluorescence (Bruker M4 Tornado) was used.Result of these tests is shown on Table 1.Sand used is free from deleterious matters and has a specific gravity of2.59 and compacted bulk density of 1720 kg/m3. The size falls within the range of 0.08mm to 2.36mm as shown on Figure 1. Cement used is ordinary Portland cement of grade 42.5 conforming to BS 12(1978). Its specific gravity and bulk density are 3.15 and 1630 kg/m3 respectively.

Controlvolumetric mix ratio for sandcrete block is 1: 6 corresponding tocement: sand. Cement is replaced (volumetric replacement) by sawdust ash at 5%, 10%, 15%, 20% and 25% levels. A constant water-cement ratio (by mass) of 0.6 was used. Three hollow blocks of 450 x 225 x 225 mm was molded for each mix ratio. The mold was heap-filled (filling above the top surface of the mold till the heap can no longer retain additional sandcrete) with loose sandcrete and lifted up to a height of 300 mm and allowed to fall freely to the ground for compaction. This lifting up and free-falling-down was repeat two more times making a total of three free-fall-compactions. Additional loose sandcretewas heaped on the compacted sandcrete in the mold and a wood board (500 x 300 x 50 mm in dimension) was placed on the heap. A sand filled bag weighing 50 kg was lifted to a height of 300 mm above the board and allowed to free-fall on the board three times. The board was then used to level the compacted sandcrete in the mold. The sandcretewas removed from the mold and placed on a level wooden platter for curing. The molded blocks were covered with a cloth (something like blanket), which was kept moist throughout the curing period. This kept the blocks moistened during the period.After curing the blocks were allowed to surface dry and tested for saturated surface dry (SSD) density and compressive strength in conformity with BS 1881: Part 115 (1986).

III. RESULTS AND DISCUSSIONS

The chemical composition and physical properties of the sawdust as are presented on Table 1. It can be seen that calcium oxide dominated other oxides. More so, the amounts of silica and alumina are very small, which justifies the thorough washing of the sawdust before combustion. Furthermore, it is obvious that the ash obtained herein is a typical biomass ash, which was contaminated very little by the soil. The pozzolanicity of the ash is almost zero, hence, pozzolanic action in sandcrete is not expected.The relationship between cement content and 28 dyas compressive strength is presented on Figure 2. Similarly, the relationships between SSD density and 28 days compressive strength and between days of curing and compressive strength are respectively presented on Figures 3 and 4. A critical look at Figures 2 and 3 reveals linear relations. As the cement content increases, the 28 days strength increase. Also, as the SSD density increases the compressive strength increases. Figure 4 reveal a parabolic relationship between days of curing and compressive strength for sandcrete with no ash. Table 2 did not show any indication that pozzolanic action took place as the compressive strength was reducing with reduction in cement content forall the curing days. However, the density of the sandcrete is decreasing as the cement content is decreasing. This fit is expected because the specific gravity of the cement is higher than that of sawdust ash.

In conclusion, it is obvious herein that ash from cleansawdustbiomass(with traces of soil impurities) contains only traces of pozzolanic oxide and consequently impacts no pozzolanic actions on sandcrete block when it is used to partially replace cement. More so, compressive strength of sandcrete blocks increases linearly with increase in cement content and with increase in saturated surface dry density. It reduces linearly with increase in ash from clean sawdust biomass. The compressive strength also increases parabolic with curing age and this increase appears to flatten as curing age reaches 90 days and more.

Future studies should investigate other benefits of using ash from clkuean sawdust biomass on sandcrete blocks. Some would be benefits can include durability, reduction in water absorption, reduction in abrasion etc.Furthermore, future studies should investigate if the inclusion of ash from clean sawdust biomass can improve the rendering quality of sandcrete (or mortar) for rendering of walls.

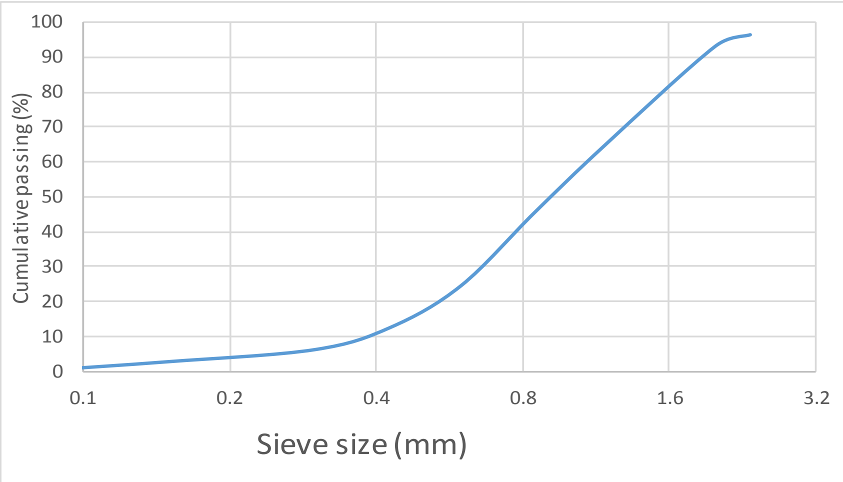

Figure 1: Grain size distribution of the sand

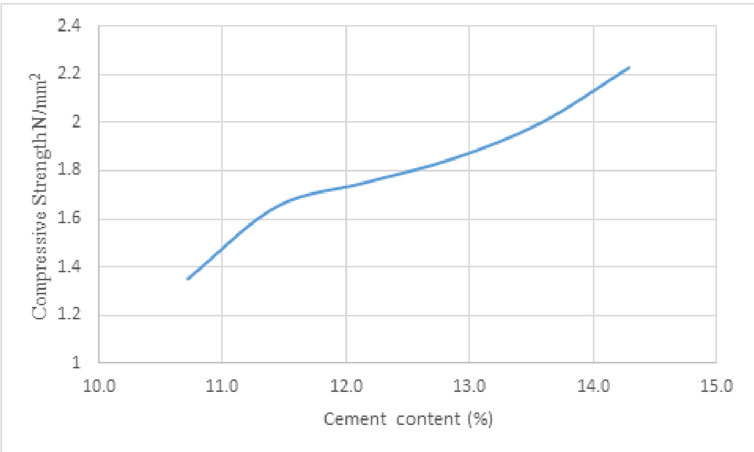

Figure 2: Relationship between cement content and 28 days compressivestrength

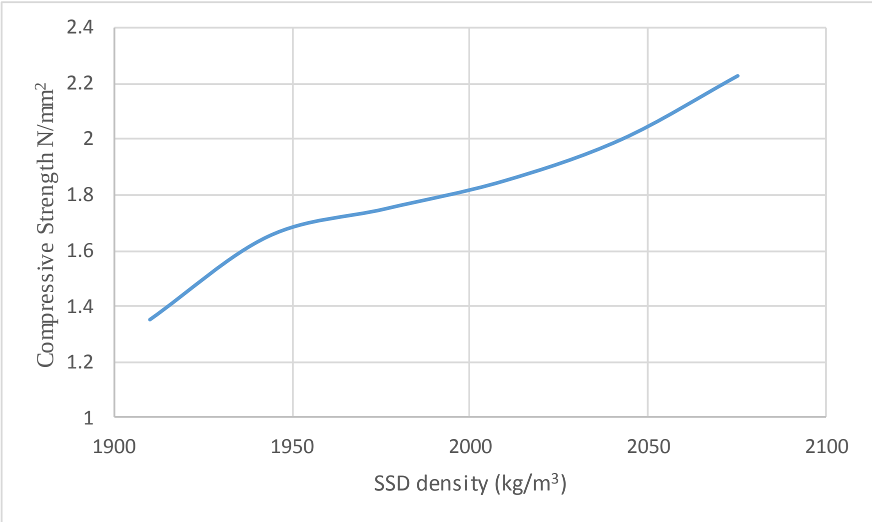

Figure 3: Relationship between SSD density and 28 days compressive strength

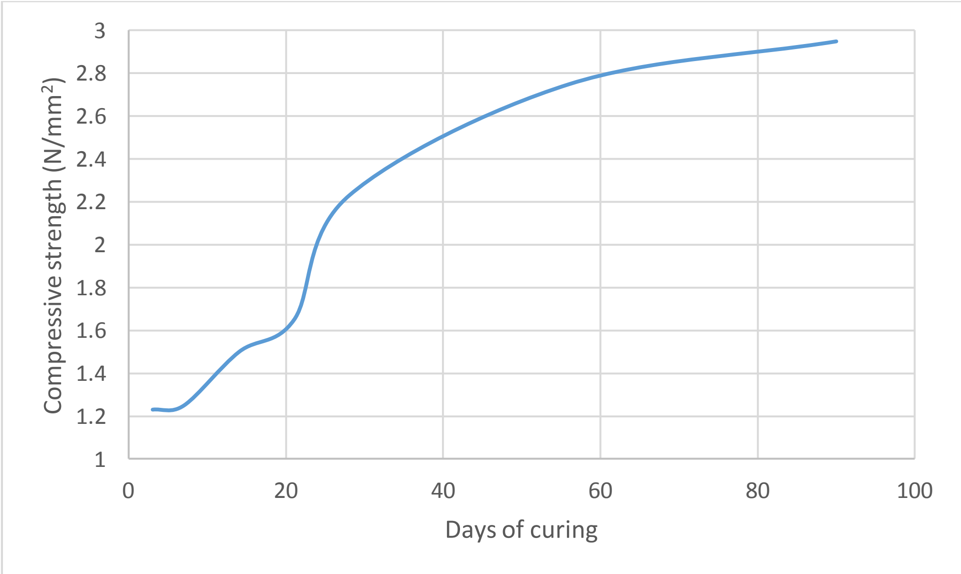

Figure 4: Relationship between days of curing and compressive strength

Table 1: Chemical composition and Physical properties

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	
0.47	0.23	0.23	51.78	9.23	2.97	0.1	
K_2O	ZnO	P_2O_3	MnO	LOI	Specific gravity	loose Bulk density (kg/m³)	Fineness modulus
12.72	0.1	2.87	0.92	16	2.15	815	1.85

Table 2: Compressive strength of the blocks (N/mm²)

Curing Age (Days)	0% Rep.	5% Rep.	10% Rep.	15% Rep.	20% Rep.	25% Rep.
3	1.23	0.75	0.65	0.5	0.5	0.35
7	1.25	1.2	0.75	0.68	0.65	0.43
14	1.5	1.48	1	0.85	0.83	0.63
21	1.65	1.75	1.5	1.65	1.5	1.23

28	2.23	2	1.85	1.75	1.75	1.35
56	2.75	2.45	2	1.85	1.87	1.75
90	2.95	2.62	2.15	1.95	1.91	1.79

Table 3: Bulk density of the blocks (kg/m^3)

Curing Age (Days)	0% Rep.	5% Rep.	10% Rep.	15% Rep.	20% Rep.	25% Rep.
3	2073.3	2040.3	2007.5	1974.4	1940.7	1908.5
7	2074.2	2041.6	2007.4	1975.6	1942.3	1909.4
14	2075.5	2041.6	2009.3	1975.7	1944.7	1911.8
21	2074.6	2041.4	2008.5	1975.4	1942.5	1909.5
28	2075.6	2042.8	2009.7	1976.5	1943.5	1910.3
56	2075.8	2042.2	2008.9	1977.4	1944.4	1910.1
90	2075.6	2042.5	2009.5	1976.9	1943.6	1911.4

Table 4: Water absorption on blocks

Percentage replacement	Average Weight (Kg) of blocks		Weight (kg) of Absorbed water	Water absorption Rate (%)
	Before immersion	After 24 hours immersion		
0	15.67	16.76	1.09	6.96
5	16.71	17.9	1.19	7.12
10	15.88	18	2.12	11.35
15	15.89	17.95	2.06	12.96
20	15.73	17.95	2.22	14.11
25	16.1	18.51	2.41	14.97

REFERENCE

[1]. ASTM C 618 (1994)

[2]. Afolayan, J. O., Ijimdia, S. T. and Oriola, F. O. P. (2017). Effect of water-cement ratio on the compressive strength of sandcrete block blended with sawdust ash. International Journal of Development Research Vol. 07, Issue, 09, pp.14923-14928, September, 2017

[3]. BS 1881 part 116, (1986). Methods of Determining Compressive Strengths of Concrete Cubes NIS 87:2000, "Nigerian Industrial Standard: Standard for Sandcrete blocks," ed: Standard Organization of Nigeria, Lagos, Nigeria.

[4]. Campbell, A.G. (1990). Recycling and disposing of wood ash. Tappi J. 73 (9), 141–146.

[5]. Cheah Chee Ban and MahyuddinRamli (2011). Properties of high calcium wood ash and densified silica fume blended cement. International Journal of the Physical Sciences Vol. 6(28), pp. 6596-6606, 9 November, http://www.academicjournals.org/IJPS. DOI: 10.5897/IJPS11.1485

[6]. Elinwa A.U., Ejeh, S. P. (2004). Effects of incorporation of sawdust incineration fly ash in cement pastes and mortars. Journal of Asian Arch. Build. Eng., 3(1): 1-7.

[7]. Elinwa, A. U. and Mahmood, Y. A. (2002). Ash from timber waste as cement replacement material. Cement Concrete Composite, 24: 219-222.

[8]. Elinwa, A. U., Ejeh, S. P. and Mamuda, A. M. (2008). Assessing of the fresh concrete properties of self-compacting concrete containing sawdust ash. Construction Building Materials, 22: 1178-1182.

[9]. GrzegorzZajac , Joanna Szyszlak-Bargłowicz , WojciechGoł ̨ebiowski and MałgorzataSzczepanik (2018). Chemical Characteristics of Biomass Ashes. Energies 2018, 11, 2885; pp. 1-15. doi:10.3390/en11112885

[10]. Hakkila, P. (1989). Utilisation of Residual Forest Biomass. Springer series in Wood Science, Springer Verlag, Berlin, 568 pp.

[11]. J. C. EZEH, O. M. IBEARUGBULEM and L. Anyaogu (2010), OPTIMIZATION OF COMPRESSIVE STRENGTH OF CEMENT-SAWDUST ASH SANCRETE BLOCK USING SCHEFFE'S MATHEMATICAL MODEL, International Journal of Engineering, Vol. 4, No. 4, pp. 487-494

[12]. J. C. Ezeh and Owus M. Ibearugbulem (2010). Optimization model for compressive strength of sandcrete blocks, International Journal of Applied Engineering Research, Vol. 5 Number 19, pp. 3203-3209 ISSN: 0973-4562

[13]. Lucie Fusade, Heather Viles, Chris Wood, Colin Burns (2019). The effect of wood ash on the properties and durability of lime mortar for repointing damp historic buildings. Construction and Building Materials 212. Elsevier Ltd. Pp.500–513. https://doi.org/10.1016/j.conbuildmat.2019.03.326

[14]. Mahendra K. Misra, Kenneth W. Ragland and Andrew J. Baker (1993). Wood ash composition as a function of furnace temperature.

[15]. Muse, J. and Mitchell, C. (1995). Paper mill boiler ash and lime by-products as soil liming materials. Agron. J. 87, 432–438.

[16]. Pieter D. Kofman (2012). Wood ash. COFORD, Processing / Products No. 43, http://www.coford.ie/media/coford/content/publications/projectreports/cofordconnects/cofordconnectsnotes/00675CCNPP43Revised091216.pdf

[17]. Pitman (2006). Wood ash use in forestry – a review of the environmental impacts Materials. Forestry, Vol. 79, No. 5, 2006. Pp. 563-588. doi:10.1093/forestry/cpl041

[18]. Qian Kang, Lise Appels, Tianwei Tan, and RafDewil (2014). Bioethanol from Lignocellulosic Biomass: Current Findings Determine Research Priorities. Hindawi Publishing Corporation, The Scientific World Journal, Volume 2014, Article ID 298153, pp. 1-13, http://dx.doi.org/10.1155/2014/298153

[19]. Raheem, A. A. (2006). Comparism of the Quality of Sandcrete Blocks Produced by LAUTECH Block Industry with others within Ogbomoso Township. Science Focus, 11 (1), pp 103-108.

[20]. Udoeyo, F. F. and Dashibil, P. U. (2002). Sawdust ash as concrete material. Journal of Materials in Civil Engineering, 14(2): 173-176.

[21]. Udoeyo, F. F., Inyang, H., Young, D. T. and Oparadu, E. E. (2006). Potential of wood waste ash as an additive in concrete. Journal of Materials in Civil Engineering, 18: 605-611

[22]. Vassilev, S. V., Baxter L., Anderson, L. K. and Vassileva, C. G. (2010). An overview of the chemical composition of biomass. Fuel 2010; 89:9, pp. 13–33.

[23]. Wang, S., Llamazos, E., Baxter, L. and Fonseca, F. (2008). Durability of biomass fly ash concrete: Freezing and thawing and rapid chloride permeability tests. Fuel, 87(3): 359-364.

Nwachukwu, A. N, et. al. "Investigation of Pozzolanic Action of Biomass Ash from Clean Sawdust on Sandcrete Block." *The International Journal of Engineering and Science (IJES)*, 10(02), (2021): pp. 24-29.