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SUITABILITY OF AGRICULTURAL BY-PRODUCTS IN NIGERIA AS PARTIAL REPLACEMENT TO CEMENT IN INFRASTRUCTURAL PROJECTS: A REVIEW

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ABSTRACT
High cost of Portland cement had hindered the availability of affordable infrastructure in materials as alternative relying on locally available and otherwise wastes from agricultural produce. Utilization of agricultural by-products as partial replacement to cement will reduce their environmental challenges and increase the affordability of cement based infrastructures since cement constitute a major proportion of the costs. Most agricultural by-product ashes have been found to improve the strength properties of cement based material especially at their later ages. The durability of cement based materials such as chloride ion permeability, porosity, water absorption and thermal conductivity is substantially improved. Nigerian agricultural sector is still dominated by subsistence farming, however, rice husk and saw dust could be available in commercial quantity in rice and timber mills respectively.

KEYWORDS: Agricultural by-product, Cement Pozzolana, Infrastructural Project, Partial Replacement

1 INTRODUCTION

Concrete is a construction material made by mixing cement, fine aggregate, coarse aggregate and water in the appropriate proportions. It is a mixture of paste and aggregates or rocks. The paste consists of Portland cement and water, coats and bond with fine and coarse aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete. Aggregate in a concrete mix consists of coarse aggregates such as granite, limestone or other geologic minerals and fine aggregates such as fine sand. Cement is a material with cohesive and adhesive properties when mixed with water, which makes it capable of bonding materials fragments into a compact whole [1]. Cements are classified as calcium silicate and calcium aluminate cement. Calcium silicate cement is further classified into Portland and slag, while calcium aluminate cement is classified into high alumina and pozzolana cements [2].

A pozzolana is a siliceous/aluminate material which in itself has little or no cementitious value, but which will in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide liberated during the hydration of Portland cement to produce stable, insoluble cementitious compound which contributes to its strength and impermeability [3]. Calcium hydroxide [$Ca(OH)_2$] or lime is one of the hydration products of Portland cement and it greatly contributes towards the deterioration of cement composites. When a pozzolana is blended with Portland cement , it reacts with the lime to produce additional calcium-silicate-hydrate (C-S-H), which is the main cementing compound. Thus the pozzolanic material reduces the quantity of lime and increases the quantity of C-S-H. Therefore the cementing quality is enhanced if a pozzolana is blended in suitable quantity with Portland cement [4 - 7].

Supplementary cementitious materials have been proven to be effective in meeting most of the requirements of durable concrete and blended cements are now used in many parts of the world

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[8]. Agricultural by-products regarded as waste in technologically underdeveloped societies could be used as partial replacement of Portland cement to achieve this purpose [9]. Agricultural by-product pozzolanas have been used in the manufacture and application of blended cements [10]. Research indicates that agricultural by-products that are rich in amorphous silica can be used as partial replacement to cement [11 – 14]. [15] suggest that soil, climatic and geographical conditions could affect the physical and chemical properties and consequently the pozzolanicity of agricultural by-products.

2 ECONOMIC ASPECTS AND ENVIRONMENTAL IMPLICATIONS.

In developing countries like Nigeria, proper utilization of agricultural by-products has not been given due attention. The utilization of supplementary cementitious materials in either cement or concrete can compensate for environmental, technical and economic issues caused by cement production. Most of these supplementary cementing materials are agricultural by-products, and their inclusion serves as an invaluable means to protect environmental resources, which may result in more viable construction in the future [16].

Portland cement as an ingredient in concrete is one of the most widely used construction materials, especially in developing countries. The cement production rate of the world was estimated at 1.2 billion tons/year as at 2011, which was expected to grow to about 3.5 billion tons/year by 2015 [17].

In cement industries, continuous attempts are being made to reduce the cost of production of Portland cement, to reduce the consumption of raw materials, to protect the environment and to enhance the quality of cement. One way is to use certain low cost materials for partial replacement of Portland cement clinker. Low cost materials used are industrial and agricultural by-products. Mixture of Portland cement and the above by-products are known as blended cements or composite cements. Blended cements are hydraulic binders in which a part of Portland cement is replaced by other hydraulic or non-hydraulic material [5].

Cement concrete is the most widely used building material due to its satisfying performance in strength requirements and its ability to be moulded into a variety of shapes and sizes. Construction work globally is increasing at alarming rate with substantial consumption of cement in large proportion hence the need for full or partial replacement [18].

The tremendous increase in building and civil engineering construction necessitated by the need for the provision of shelter and infrastructure for the increasing population has consequently led to the corresponding increase in the use of concrete. Since the conventional concreting materials have always been cement, sand and aggregate, the prices of which are on the rise, a spectacular search for replacement of the conventional materials with locally sourced materials which are regarded as waste has recently been on the increase [19, 11].

The cost of building construction is increasing daily as a result of increase in the cost of building materials such as cement. This has prevented the low income earners to have their own house. Agricultural by-products pose great hazard to environment and man as a result of improper management, even when these material are burnt, they release carbon-monoxide to the atmosphere which deplete the ozone layer. If these materials are processed, they may be suitable for construction purposes [20, 21].

The pollution associated with cement production, has necessitated a search for an alternative binder which can be used solely or in partial replacement of cement in concrete production. Disposal of agricultural by-products have constituted an environmental challenge, hence the need to convert them into useful materials to minimize their negative effect on the environment [22].

Globally, approximately 600 million tons of rice paddy is produced each year. On average 20% of the rice paddy is husk, giving an annual total production of 120 million tons. In the majority of producing countries much of the husk produced from the processing of rice is either burnt or dumped as waste. Ordinary Portland cement (OPC) is expensive and unaffordable to a large portion of the world's population. Since OPC is typically the most expensive constituent of concrete, the replacement of a proportion of it with RHA offers improved concrete affordability, particularly for low-cost housing in developing countries [23, 24]. The partially burnt rice husk contributes to environmental pollution [15].The rice husk thereby constitutes an environmental nuisance as they form refuse heaps in the areas where they are disposed. The use of rice husk ash as partial replacement to cement will provide an economic use of the by-product and consequently produce cheaper blocks for low cost buildings [25].

Corn cobs are agricultural by-products which are dumped as waste in large quantities during corn season and they impose hazards to the environment in open dumps located in most cities

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in Nigeria.The utilization of corn cob for production of concrete will go a long way in not only the reduction of overall cost of the concrete but also reduce the quantity of the waste in the environment [26]. Corn cob ash (CCA) could be used as a pozzolana to mitigate on the cost of cement and its negative impacts on the environment [27].

According to [28], the use of plant ashes such as saw dust ash, maize cob ash and sugarcane bagasse ash as cement replacement should be encouraged for use in concrete to reduce environmental degradation associated with mining of cement manufacturing materials. This would also reduce construction budget associated with the high cost of cement since blended concrete of higher strength can be made with longer curing periods.

3 STRENGTH PROPERTIES

The use of pozzolana can lead to increased compressive and flexural strengths [29]. 5-20% replacement of cement with RHA helps the concrete in possessing desirable compressive strength and flexural strength [30]. Portland cement could partially be substituted with ungrounded RHA to level of 17.5% to produce sandcrete blocks as building units [31]. RHA is highly pozzolanic and can be used as a supplementary cementing material to produce high strength concrete [32]. The usual reduction of slump of fresh concrete associated with the use of RHA in concrete can be reduced by presoaking RHA in equal mass of water prior to mixing [33].

Residual RHA provides a positive effect on the compressive strength of concrete at early ages, but the long term behaviour was more significant. Also the result of splitting tensile strength reveals the pozzolanic effect for concrete with residual RHA [34].

Investigation on the strength of high strength rice husk ash cement concrete show that RHA can be an alternative material in the production of high strength concrete since it can be produced at a much lower cost [35].

The higher compressive strength of the RHA concrete compared with that of the control is due probably to the reduced porosity, reduced $Ca(OH)_2$ and reduced width of the interfacial zone between the paste and the aggregate [36].

RHA at a low specific surface was reactive in normal strength concrete, thus indicating that commercial mill could be used to produce RHA for concreting [37].

[38] investigated the influence of particle size and specific surface area on the pozzolanic activity of residual rice husk ash and found that the pozzolanic activity of RHA evaluated by compressive strength tests correlated to particle size through an inverse log-linear relationship.

The strength variation of OPC-RHA composite suggest that with good quality control of the concreting process, 5% to 30% OPC replacement with RHA could be suitable for reinforced concrete works and 35% to 50% for minor works in concrete [39].

RHA concrete can be effectively used as light weight concrete for the construction of structures where the weight of structure is of supreme importance [40].

Agricultural by-products such as corn cob ash (CCA) shows good pozzolanic property in the production of sandcrete blocks [41].

Granulate corn cob, without containing any corn, is proposed as an alternative organic aggregate lightweight concrete. It may also be suitable for non-structural application purposes [42].

[43] evaluated blended cement mortar, concrete and stabilized earth made from ordinary portland cement (OPC) and corn cob ash (CCA) and found that there is no significant difference between the strength of concrete produced with 0.0% and 20.0% CCA. Also Portland cement replaced by weight with CCA produces stabilized clay and laterite exhibiting greater strength than plain cement stabilized earth.

[44] investigated the strength development of corn cob ash cement concrete, the result show that the compressive strength of 10% CCA replacement concrete at 60 days was 3.3% greater than the strength of the conventional concrete. With addition of 2% superplasticizers, the 28 days compressive strength of 10% CCA replacement was 7% greater than the strength of the conventional concrete. The strength was increasing with respect to increase of curing days and decreasing with increase of CCA percentage. Workability of CCA concrete mix decreased with increase of CCA percentage, so it required more water to make the mix more workable.

[27] on the viability of using corn cob ash as a pozzolana in concrete inferred that the CCA used did not satisfy the minimum chemical composition requirement for pozzolanic material of $SiO_2 + Al_2O_3 + Fe_2O_3 \geq 70\%$, it satisfied the requirement of SiO_2 content of not less than 25%. The chemical composition of CCA can however be improved by incinerating corn cobs under controlled conditions. The compressive strength and sulphate resistance tests showed good prospects, with strengths

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capable of structural application being observed over all replacements.

[45] studied the strength characteristics of laterized concrete with corn cob ash (CCA) blended cement and found that concrete made with 10% CCA has the optimum flexural and compressive strength compared to other replacement levels of CCA and can thus be recommended for use in low cost housing construction.

[46] studied the strength properties of corn cob ash concrete and inferred that corn cob ash do not attain their design strength at 28 days and that the strength of CCA concrete is dependent on its pozzolanic activities.

[47] investigated the strength characteristics of binary blended cement concrete made with ordinary Portland cement and each of eight agricultural by-products in South Eastern Nigeria namely rice husk ash (RHA), saw dust ash (SDA), oil palm bunch ash (OPBA), cassava waste ash (CWA), coconut husk ash (CHA), corn cob ash (CCA), plantain leaf ash (PLA) and paw-paw leaf ash (PLA). They found that all eight agricultural by-products are reasonably pozzolanic since the fix some quantities of lime over time thereby reducing the alkalinity of their mixture with calcium hydroxide as reflected in smaller titre values recorded over time compared to the blank titre. They however recommended that structural elements constructed with blended cement concrete should be allowed a longer time before loading as it takes a longer time to attain adequate strength than 100% OPC concrete.

Comparative analysis of properties of rice husk ash (RHA), corn cob ash (CCA) and sheanut shell ash (SSA) in concrete production show that all the three materials are suitable for use as pozzolana [48].

[49] on the use corn cob ash (CCA) and saw dust ash (SDA) as cement replacement in concrete works recommended its use in plain concrete and non-load bearing structure and that 10% CCA-SDA replacement is adequate for maximum benefit of strength gain.

[50] investigated the effect of palm bunch ash on concrete properties and inferred that there is a decrease in compressive, flexural and split tensile strengths at 7 and 28 days as the palm bunch ash (PBA) content is increased. Optimum cement replacement with PBA occurs at 5% PBA replacement level.

[51] investigated coconut shell ash (CSA) as partial replacement of ordinary Portland cement in concrete production, they found that 10 to 15% partial replacement of OPC with CSA using water cement ratio of 0.5 are suitable for production of both normal and lightweight concrete.

A possibility exists for the partial replacement of sand and granite with saw dust and palm kernel shell in the production of lightweight concrete. However, organic materials are subject to deterioration over time hence saw dust and palm kernel shell should be regularly maintained and replaced when necessary [52].

[53] reviewed the impact of saw dust and crushed waste glass in the properties of sandcrete blocks. [54] investigated the pozzolanic properties of bamboo leaf ash (BLA) in a bleneded Portland cement. [55] studied the performance of coconut shell ash and palm kernel ash as partial replacement for cement in concrete. [12] investigated the suitability of saw dust ash –lime mixture for production of sandcrete block and inferred that saw dust ash has a fairly significant effect on the compressive strength of sandcrete blocks.

Saw dust concrete can be used as lightweight concrete with a satisfactory strength performance.

A study of the flexural and compressive strength characteristics of cement-cassava peel ash (CPA) blended concrete show that CPA appears to contribute to late strength development of concrete when up to 15% by weight of cement is used as indicated by the Strength Activity Index (SAI) which is above minimum recommended of 75% at 28 days and above [56].

[57] investigated the effect of utilizing locally available lateritic soil on strength behaviours of concrete under short term hydration with the addition of locally available pozzolanic cassava peel ash partly replacing cement.

[58] studied saw dust ash as partial replacement to cement and found that the compressive strength of concrete at 5% replacement with saw dust ash was higher than that of the normal concrte at 7days and 28days of curing.

[59] on the feasibility of using sea shell ash as admixtures for concrete inferred that cement can be replaced partially up to 10% by weight of periwinkle shell ash, 15% by weight of oyster shell ash and 20% of snail shell ash in mortar cubes without the strength being affected. [60] investigated the uses of saw dust ash as admixture in the production of low cost and light weight hollow blocks. [62] worked on the use of coconut fibre ash as a partial replacement for cement. [62] developed a polynomial regression model for predicting the compressive strengths for bagasse ash concrete.[63] investigated the use of saw dust ash (SDA) as partial replacement for ordinary Portland cement in sandcrete blocks and inferred

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that up to 10% SDA replacement is adequate for use in sandcrete blocks for non-load bearing wall in buildings. [64] conducted a review of the experimental study on concrete by partial replacement with coconut shell ash (CSA) and palm kernel shell ash (PKSA) and found that partial replacement of cement with 20% PKSA and CSA in concrete gives an average optimum compressive strength at 28 days, which is suitable for both light weight and normal concrete respectively. [65] investigated the strength of blended cement sandcrete and soilcrete blocks containing cassava waste ash (CWA) and plantain leaf ash (PLA) and inferred that the OPC-CWA and OPC-PLA binary blended cement could be used in producing sandcrete and soilcrete blocks with sufficient strength for use in building and minor civil engineering works where the need for high early strength is not a critical factor.

[66] on the replacement of cement with saw dust ash (SDA) stated that up to 10% SDA substitution is allowed at maximum and 5% substitution is adequate to enjoy maximum benefit of strength gain. [67] conducted an experimental study on partial replacement of fine aggregate with quart dust and saw dust. According to [68], groundnut shell ash can be used as partial replacement of cement in sandcrete block to achieve a satisfactory compressive strength at about 20% of compressive strength at about 20% of the binder quantity.

[69] investigated groundnut shell ash as partial replacement of cement in concrete and recommended a replacement of 2.5% of cement in concrete.

4 DURABILITY PROPERTIES

The durability of blended cement is higher than the ordinary Portland cement [4]. RHA cement concrete has excellent resistance to chloride ion penetration [32]. [33] found prospects in durability properties of concrete at 5% RHA content. The reduced permeability reveals the significance of the filler effect for concrete with residual RHA [34].

Highly reactive silica ash produced by incineration of rice husk ash can be successfully used in mass concrete requiring high strength without excessive rise in adiabatic temperature [70].

[71] studied the characteristics of rice husk ash (RHA) concrete including the durability aspects such as chloride ions permeability, porosity and pore structure and found that using RHA improved the properties of concrete. Introduction of up to 10% CCA in cement mixture reduces the thermal conductivity. This can enhance insulation properties of the mortar for building construction [72]. Corn cob ash (CCA) could be used with advantage in Na_2 SO_4 aggressive environments. The sulphate resistance of CCA specimens could be attributed to low level of CaO and low ratio of SO_3/Al_2O_3 [27]. [73] studied the corrosion performance of rice husk ash blended concrete and found that incorporating RHA up to 30% replacement level reduces the chloride penetration, decreases permeability, improves strength and corrosion resistant properties. [6] studied the pozzolanic properties of rice husk ash by hydrochloric acid pretreatment and found that with hydrochloric acid pretreatment of rice husk, the pozzolanic activity of RHA is not only stabilized, but also enhanced; the sensitivity of the pozzolanic activity of the RHA to burning conditions is reduced. Incorporation of corn cob ash (CCA) in blended cement mortar cubes decreases the thermal conductivity and improves the insulation properties of the specimens. The implication is that the use of CCA –blended cement in mortar used for plastering and floor screeding would improve the thermal comfort in buildings thereby reducing the cost of energy required for cooling thus, leading to energy conservation [17]. [43] evaluated blended cement mortar, concrete and stabilized earth made from ordinary portland cement (OPC) and corn cob ash (CCA) and found that replacing 20.0% of cement with CCA in concrete mix and mortar improves water absorption and durability of the specimens. Also Portland cement replaced by weight with CCA produces stabilized clay and laterite exhibiting lower thermal conductivity and lower water absorption than plain cement stabilized earth. [74] investigated the durability of concrete produced using blended cement, which incorporates CCA as a pozzolana. They found that the addition of CCA reduces the water absorption of concrete specimens, optimum reduction occurred at 10% CCA replacement for 1:1.5:3 and 1:2:4 mix proportions and 15% CCA replacement for 1:3:6 mix proportion. The resistance of the mortar cubes to chemical attack was improved as the addition of CCA up to 15% replacement caused a decrease in permeability. [75] investigated the effect of bamboo leaf ash blended cement on engineering properties of lateritic blocks and inferred that resistance to water penetration was good with lateritic blocks produced with 5 to 15% cement substitution but not so good for higher levels of substitution.

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5 CONCLUSION AND RECOMMENDATION

Most agricultural by-products are generally pozzolanic with good prospects as partial replacements to cement in concrete, sandcrete and other areas of applications. They have been found to improve the compressive and flexural strengths especially at later days of curing and the durability properties such as chloride ion permeability, porosity, water absorption and thermal conductivity. Utilization of agricultural by-products as partial replacement to cement will reduce their environmental challenges and increase the affordability of infrastructures since cement constitute a major proportion of the costs.

According to the agricultural poll conducted in 2016, Nigeria's agricultural sector is still dominated by subsistence farming. Rice husk and Saw Dust have adequate cluster and could be available in commercial quantity in rice and timber mills respectively, but in terms of material composition, saw dust may not give a reliable result as there is a need to study the chemical and physical properties of the various tree species from which the ashes used is gotten. This will show the difference in composition and pozzolanic activity if any, among the ashes of different tree species.

REFERENCES

[1] Neville, A. M. "Properties of Concrete" 3rd Edition, Longman Scientific and Technical Publishing, London, pp. 58-70, 1996.

[2] Jackson, N and Dhir, R. K. "Civil Engineering Materials" 4th Edition, Macmillan ELBS, Hong Kong, pp.144-160, 1991.

[3] Sima, J. "Portland-Pozzolana Cement: Need for a Better Application" Indian Concrete Journal, 48, pp. 33- 34, 1974.

[4] Padney, S. P., Singh, A. K., Sharma, R. L and Tiwari, A. K " Studies on High-Performance Blended/Mult-iblended Cements and Their Durability Characteristics" Cement and Concrete Research, vol. 33, Isssue 9, pp. 1433-1436, 2003.

[5] Dwivedia, V.N., Singh, N.P., Das, S.S and Singh N.B. " A new pozzolanic Material for Cement Industry: Bamboo Leaf Ash" International Journal of Physical Science, http://www.academicjournals.org/IJPS, vol.1, ISSN: 1992-1950, Issue 3, pp.106-111, 2006.

[6] Feng. Q, Yamamichi, H, Shoya, M and Sugita,S. "Study on the pozzolanic properties of Rice Husk Ash by Hydrochloric Acid Pre-treatment" Cement and Concrete Research, vol.34, pp.521-526, 2004.

[7] Qijun,Y., Sawayama, K., Sugita, S and Isojima,Y. " Reaction Between Rice Husk Ash and $Ca(OH)_2$ Solution and the Nature of its Product" Cement and Concrete Research, vol. 29, Issue 1, pp.37-43, 1999.

[8] Bakar B .A, Putrajaya .R .C &Abdulaziz .H. "Malaysian Saw Dust Ash, Improving the Durability and Corrosion Resistance of Concrete" Pre-review, Concrete Research Letters vol 1, no 1 pp. 6-13, 2010.

[9] Ettu, L.O., Mbajiorgu, M.S.W., Njoku, F.C., Arimanwa, J.I., and Amanze, A.P.C. "Prospect of Nigerian Agricultural by-Products Ashes for Blended Cement Making" International Journal of Civil Engineering Research and Application (IJCERA), vol.1, Issue 4, pp.1-9, 2013a.

[10] Malhotra, V. M and Mehta, P. K. " Pozzolanic and Cementitious Materials" London: Taylor and Francis, 2004.

[11] Aho, M. I and Utsev, J. T. " Compressive Strength of Hollow Sandcrete Block Made with Rice Husk Ash as a Partial Replacement to Cement" Nigerian Journal of Technology, vol. 27, No. 2, pp. 71-77, 2008.

[12] Tyagher, S. T., Utsev, J. T and Adagba, T. " Suitabilty of Saw Dust Ash-lime Mixture for production of Sandcrete Hollow Blocks" Nigerian Journal of Technology, vol. 30, No. 1, pp. 79-84, 2011.

[13] Naji, A. G., AbdulRasheed, S., Aziz, A. F. N and Salleh, M. A. M. "Contribution of Rice Husk Ash to the Properties of Mortar and Concrete: A Review" Journal of American Science, vol. 6, Issue 3, pp. 157-165, 2010.

[14] Nwadiogbu, C.P. " Effect of Elapsed Time on Laterite Modified with Lime and Locust Beans Waste Ash" Unpublished M.Sc Research Submitted to post Graduate School, Ahmadu Bello University, Zaria, 2010.

[15] Chandrasekhar, S., Satyanarayana, K. G., Pramada, P. N., Raghavan, P., and Gupta, T. N. "Review Processing, Properties and Application of Reactive Silica From Rice Husk Ash, An Overview" Journal of Material Science, vol. 38, Issue 15, pp. 31-59, 2003.

[16] Owaid, H. M., Hamid, R. B and Taha, M. R. "A Review of Sustainable Supplementary Cementitious Materials as an Alternative to All-Portland Cement Mortar and Concrete" Australian Journal of Basic and Applied Science, ISSN: 1991-8178, vol. 6, Issue 9, pp. 287-303, 2012.

[17] Raheem, A. A and Adesanya, D. A. "A Study of Thermal Conductivity of Corn Cob Ash Blended Cement Mortar" The Pacific Journal of Science and Technology, http://www.akamaiuniversity.us/PJST.htm, vol. 12, Num. 2, pp. 106-110, 2011.

[18] Oluborode, K and Olofintuyi, I. " Self-Compacting Concrete: Strength Evaluation of Corn Cob Ash in a Blended Portland Cement" American Scientific Research Journal for Engineering, Technology and Sciences (ASRJETES), ISSN(print): 2313-4410, ISSN(online): 2313-4402, pp. 123-130, 2015.

[19] Ujene, A. O and Achuenu, E. " Comparative Assessment of Compressive Strength of Concrete Containing Agricultural and Environmental Cementitious Wastes in Nigeria" Nigerial Journal of Agricultural, Food and Environmental, vol. 9, Issue 4, pp. 37-42, 2013.

[20] Zerdi, T.A, Yousuf, M., and Jaleel, M. "Partial Replacement of Sand with Saw Dust and Cow Dung in M15 Grade Concrete Production" Indian Journal of Research, ISSN:2250-1991, vol.5, Issue 5, pp.163-164,2016.

[21] Oyekan, G.L and Kamiyo, O.M " Effect of Nigerian Rice Husk Ash on some Engineering Properties of Concrete and Sandcrete Blocks" 32nd Conference on Our World in Concrete and Structures, 2007.

[22] Habeeb, G. A and Mahmud, H. B. " Study on Properties of RHA and Its Use as Cement Replacement Material" Materials Research Journal, vol. 13, Issue 2, pp. 185-190, 2010.

[23] Bronzevak Ltd." Rice Husk Ash Market Study" ETSU U/00061/REP, DTI/Pub URN 03/668, 2003.

[24] Reddy, D. V and Alvarez, M. " Marine Durability Characteristics of Rice Husk Ash-Modified Reinforced Concrete" International Latin American and Caribbean Conference for Engineering and Technology (LACCET), Mayaguez, Puerto Rico, 2006.

[25] Oyetola, B.E, and Abdullahi, M. " The Use of Rice Husk Ash in Low-Cost Sandcrete Block Production" Leonardo Electonic Journal of Practice and Technologies, ISSN:1583-1078, Issue 8, pp.58-70, 2006.

[26] Bala, A., Aminulai, H. O., Abubakar, M., Abdulrahman, H. S and Musa, U. "Partial Replacement of Cement with Corn Cob Ash in Concrete Production" International Engineering Conference, www.seetconf.futminnna.edu.ng, pp. 504-509, 2016.

[27] Kamau, J., Ahmed, A., Hirt, P and Kangwa, J. "Viability of Using Corn Cob Ash as a Pozzolana in Concrete" International Journal of Science, Environment and Technology, ISSN: 2277-663X(print), ISSN: 2278-3687(online), vol. 5, No. 6, pp. 4532-4544, 2016.

[28] Okwadha, G.D.O. "Partial Replacement of Cement by Plant Solid Wash Ash in Concrete Production" IOSR Journal of Mechanical and Civil Engineering, ISSN:2278-1684 (online) ISSN:2320-334x (print), vol.13, Issue 5, pp.35-40, 2010.

[29] Otsiku Lab, Tokyo Institute of Technology.Use of Mineral Admixtures in concrete.Oyetola, E. B. And Abdullahi, M. "The use of Rice Husk Ash in Low Cost Sandcrete Blocks Production" Leonardo Electronic Journal of Practices and Technology, vol.8 pp.58-70, 2006.

[30] Kad, N and Vinod, M. "Influence of Rice Husk Ash on the Properties of Concrete" Journal of Computer Sciences and Engineering, ISSN:2456-1843, vol.1, Issue 4, pp.75-78, 2015.

[31] Agbede, I. O and Obam, S. O. "Compressive Strength of Rice Husk Ash Cement Sandcrete Block" Global Journal of Engineering Research, vol. 7 (1), pp. 43-46, 2008.

[32] Zhang, M., and Malhotra, V. M. "High-Performance Concrete Incorporating Rice Husk Ash as a Supplementary Cementing Material" International Concrete Abstracts Portal, vol. 93, Issue 6, pp. 629-636, 1996.

[33] Abalaka, A. E and Okoli, O. G. "Strength Development and Durability Properties of Concrete Containing Pre-soaked Rice Husk Ash" Construction Science. 10, 2478/cons-2013-0001, pp. 4-12, 2013.

[34] De Sensale, G. R. "Strength Development of Concrete with Rice Husk Ash" Cement and Concrete Composite. 28(2): pp. 158-160, 2006.

[35] Mahmud, H. B., Majuar, E., Zain, M. F. M., and Hamid N. B. A. A "Strength Durability and Shrinkage of High-Strength Rice Husk Ash Concrete" International Concrete Abstract Portal, vol. 228, pp. 189-212, 2005.

[36] Zhang, M. H., Lastra, R and Malhotra, V. M. " Rice Husk Ash Paste Concrete: Some Aspects of Hydration and the Microstructure of the International Zone Between the Aggregate and Paste" Cement and Concrete Research, vol. 26, Issue 6, pp. 963-977, 1996.

[37] Abalaka, A.E. "Effects of methods Incineration on Rice Husk Ash Blended Concrete" ATBU Journal of Environmental Technology, vol.5, Issue 1, pp.34-44, 2012.

[38] Cordeiro, G.C, Filho, R.D.T, Tavares,L.M, Fairbairn, E.R.M and Hempel, S. "Influence of Particle Size and Specific Surface Area on the pozzolanic Activity of Redual Rice Husk Ash" Cement and Concrete Composites, vol.33, pp.529-534, 2011.

[39] Ettu L. O, Ajoku, C.A, Nwachukwu, K.C, Anodiji, C.T.G and Eziefula, U.G "Strength Variation of OPC Rice Husk Ash Composite with Percentage Rice Husk Ash" International Journal of Applied Science and Engineering Research, ISSN:2277-9442, vol.2, Issue 4, pp.420-423, 2013b.

[40] Nagrale, S. D., Hajare, H and Modak, P. R. "Utilization of Rice Husk Ash" International Journal of Engineering Research and Application (IJERA), ISSN: 2248-9622, vol. 2, Issue 4, pp. 001-005, 2012.

[41] Dauda, A. "Exploring the Potential of Alternative Pozzolana Cement for the Northern Savanah Ecological Zone in Ghana" American Journal of Civil Engineering, ISSN: 2330-8729(print), ISSN: 2330-8737(online), vol. 4, Issue3, pp.74-79, 2016.

[42] Pinto, J., Vicira, B., Pereira, H., Carlos, J., Vilela, P., Paiva, A., Pereira, S., Cunha, V. M. C. F and Varn, H. "Corn Cob Lightweight Concrete for Non-Structural Applications" Construction and Building Materials, vol. 34, pp. 346-351, 2012.

[43] Adesanya, D. A. "Evaluation of Blended Cement Mortar, Concrete and Stabilized Earth Made From Ordinary Portland Cement and Corn Cob Ash" Construction and Building Materials 10 (6), pp. 451-456, 1996.

[44] Thamizhkodi, T and Venkatakrishnaiya, R. "Development of Corn Cob Ash Cement Concrete" International Journal of Engineering Research, http://www.ijoer.in, ISSN: 2321-7758, vol.4, Issue 2, pp. 465-470, 2016.

[45] Ikponmwosa, E. E., and Salau, M. A and Kaigama, W. B. "Evaluation of Strength Characteristics of Laterized Concrete with Corn Cob Ash Blended Cement" 2nd International Conference on Innovation Materials, Structure and Technologies, IOP Publishing doi:10:1088/1757-899X/96/1/012009, 2015.

[46] Olafusi, O and Olutoge, F. A. "Strength Properties of Corn Cob Ash Concrete" Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), ISSN: 2141-7016, vol. 3, Issue 2, pp. 297-301, 2012.

[47] Ettu, L. O., Osadebe, N. N and Mbajiorgu, M. S. W. "Suitability of Nigerian Agricultural By-product as Cement Replacement for Concrete Making" International Journal of Modern Engineering Research (IJMER), ISSN: 2249-6645, vol. 3, Issue 2, pp.1180-1184, 2013c.

[48] Tsado, T. Y., Yewa, M., Yaman, S and Yewa, F. "Comparative Analysis of Properties of Some Artificial Pozzolana in Concrete Production" International Journal

of Engineering and Technology, ISSN: 2049-3444, vol. 4, No. 5, pp. 251-254, 2014.

[49] Mujedu, K. A., Adebara, S. A and Lamidi, J. O. "The Use of Corn Cob Ash and Saw Dust Ash as Cement Replacement in Concrete Works" International Journal of Engineering and Science (IJES), ISSN(e): 2319-1813, ISSN(p): 2319-1805, vol. 3, Issue 4, pp.22-28, 2014.

[50] Otunyo, A. W and Azuma, A. G. " Investigation of the Effect of Palm Bunch Ash on Concrete Properties" Journal of Muiltidisciplinary Engineering Science Studies (JMESS), ISSN: 2458-925X, vol. 2, Issue 11, pp. 1141-1145. 2016.

[51] Utsev, J. T. And Taku, J. K. "Coconut Shell Ash as partial Replacement of Ordinary Portland Cement in Concrete Production" International Journal of Scientific and Technology Research. Vol.1, Issue 8, ISSN:2277-8616, pp.86-89, 2012.

[52] Olutoge, F. A. " Investigations on Saw Dust and Palm Kernel Shell as Aggregate Replacement" ARPN Journal of Engineering and Applied Sciences, ISSN:1819-6608, Vol.5 No.4, pp.7-12, 2010.

[53] Kumar, S. P. And Boobalam, S. C. "Impact of Saw Dust and Crushed Waste Glass in the Properties of Sandcrete Blocks. A General Review" International Journal of Advanced Scientific and Technical Research, ISSN:2249-9954, vol.1, Issue 3, pp.114-118, 2013.

[54] Olofintuyi, I.O, Oluborodo, K. D and Adegbite, I. "Structural value of Bamboo Leaf Ash as a Pozzolanic Material in a Blended Portland Cement" International Journal of Engineering Sciences and Research Technology. ISSN:2277-1655, vol.4, Issue 9, pp.171-177, 2015.

[55] Oyedepo, O. J, Olanitori, L. M and Akande, S. P. "Performance of Coconut Shell Ash and Palm Kernel Shell Ash as partial replacement for Cement in Concrete" J. Build. Mater Struct, ISSN:2353-0057, vol2, pp.18-24, 2015.

[56] Salau, M.A, Ikponmwosa, E.E, and Olonode, K. A "Structural Strength Characteristics of Cement-Cassava Peel Ash Blended Concrete" Civil and Environmental Research, ISSN:2222-1719 (print) 2222-2863 (online), vol.10, pp.68-73, 2012.

[57] Agbenyeku, E, and Aigbavboa, C. "GreenConcrete as a Useful Resource in Low –Cost Rural Housing and Development" Sustainable Industrial Processing Summit, vol.6, pp.81-88, 2015.

[58] Chugh, S and Bansal, R. "Study on Saw Dust Ash as Partial Replacement with Cement" International Journal of Engineering Technology Science and Research, www.ijetsr.com, ISSN:2394-3386, vol.3, Issue 4, pp.126-130, 2016.

[59] Etuk, R.B, Etuk, F.I and Asuquo, O.L "Feasibility of Using Sea Shell Ash as Admixtures for Concrete" Journal of Environmental Science and Engineering, vol.1, ISSN: 1934-8932, pp.121-127, 2012.

[60] Adebakin, I. H, Adeyemi, A.A, Adu, J. I, Ajayi, F.A, Lawal, A.A, and Ogunrinola, O.B. "Uses of Saw Dust as Admixture in Production of Low Cost and Light-Weight Hollow Sandcrete Blocks" American Journal of Scientific and Industrial Research, ISSN:2153-649X, vol.3, Issue 6, pp.458-463, 2012.

[61] Anifowoshe, F.A, and Nwaiwu, N.E. "The Use of Coconut Fibre Ash as a Partial Replacement for Cement" British Journal of Applied Science and Technology, ISSN:2231-0843, vol.17, Issue 5, pp.1-11, 2016.

[62] Aburili, K, Saburi, B.W and Onchiri, R.O. "Compressive Strength Prediction Model for BagasseAsh Concrete" International Journal of Novel Research in Civil Structural and Earth Sciences, ISSN:2394-7357, vol.3, Issue 3, pp. 6-14, 2016.

[63] Raheem, A.A and Sulaiman, O.K. "Saw Dust Ash as Partial Replacement for Concrete in the Production of Sandcrete Hollow Blocks" International Journal of Engineering Research and Applications, ISSN:2248-9622, vol.3, Issue 4, pp.713-721, 2013.

[64] Desai, B.M., Umravia, N., and Parikh, K.B. "Experimental Study of Concrete by Partial Replacement of Cement with Coconut Shell Ash, Incorporating Steel Fibre: A Review" International Journal of Research in Applied Science and

Engineering Technology (IJRASET), ISSN:2321-9653, vol.5, Issue 3, pp.161-164, 2017.

[65] Ettu, L.O., Mbajiorgu, M.S.W., and Arimanwa, J.J. "Strength of Blended Cement Sandcrete and Soilcrete Blocks Containing Cassava Waste Ash and Plantain Leaf Ash" American Journal of Engineering Research, e-ISSN:2320-0847, p-ISSN:2320-0936, vol.2, Issue 5, pp.55-60, 2013d.

[66] Malik, M.I, Jan, S.R., and Peer, J.A. "Partial Replacement of Cement by Saw Dust Ash in Concrete: A Sustainable Approach" International Journal of Engineering Research and Development, e-ISSN:2278-067X, p-ISSN:2278-800X, vol.11, Issue 2, pp.48-53, 2015.

[67] Suji, D., Narayanan, A.M., Kumar, K., and Perarasan, M.C. "Experimental Study on Partial Replacement of Fine Aggregate with Quarry Dust and Saw Dust" International Journal of Advancement in Engineering Technology, Management and Applied Science, ISSN:2349-3224, vol.3, Issue 6, pp.42-54, 2016.

[68] Mahmud, H., Belel, Z.A., and Nwakaire, C. "Groundnut Shell Ash as a Partial Replacement of Cement in Sandcrete Blocks production" International Journal of Development and Sustainability, ISSN:2186-8662, vol.1, No3, pp.1026-1032, 2012.

[69] Krishanan, C.N., and Nizar, N.M. "Groundnut Shell Ash as Partial Replacement of Cement in Concrete"IJRDO-Journal of Mechanical and Civil Engineering, ISSN:2456-1479, vol.2, Issue 2, pp.39-48, 2016.

[70] Mehta, P. K and Pirtz, D. "Use of Rice Husk Ash to Reduce Temperature in High- Strength Mass Concrete" ACI Journal Proceedings, 75. pp. 60-63, 1978.

[71] Anwar, M., Miyagawa, T., and Gaweesh, M., "Using Rice Husk Ash as Cement Replacement Material in Concrete" Waste Management Series, vol.1, pp. 671-684, 2003.

[72] Price, A., Yeargin, R., Fini, E and Abu-Lebeh, T. "Investigating Effects of Introduction of Corn Cob Ash into Portland Cement Concrete: Mechanical and Thermal Properties" American Journal of Engineering and Applied Sciences, ISSN: 1941-7020, vol.7, Issue 1, pp. 137-148, 2014.

[73] Savaswatty, V, and Song H.W. "Corrosion performance of Rice Husk Ash Blended Concrete" Construction and Building Materials, vol.21, pp.1779-1784, 2006.

[74] Adesanya, D. A and Raheem, A. A. "A Study of the Permeability and Acid Attack of Corn Cob Ash Blended Cements" Construction and Building Materials, vol. 24, pp. 403-409, 2010.

[75] Utodio, N.F, Ekanem, E. S, Egege, C. C, Ocholi, M, Afakpu, O. D and Nwigwe, D.N. "Investigation of the Effect of Bamboo Leaf Ash Blended Cement on Engineering Properties of Lateritic Blocks" Journal of Sustainable Development Studies, ISSN:2201-4268, vol.8, No.1, pp.193-208, 2015.