Global Scientific JOURNALS

GSJ: Volume 7, Issue 11, November 2019, Online: ISSN 2320-9186
www.globalscientificjournal.com

PARTIAL REPLACEMENT OF CEMENT WITH CORN COB ASH – A REVIEW

Olukotun Adebisi, Audu Mohammed Taiwo, Obafaye Babatunde Julius, Abiodun Ebenezer Olusola
Oseni Olumide Williams

Department of Civil Engineering, University of Abuja

Abstract: *The most common material used for construction is concrete with its major constituent being cement. Cement production results in a lot of environmental pollution as* CO_2 *gas is constantly emitted. Supplementary cementitious materials like saw dust ash, rice husk ash, egg shell powder, sugarcane bagasse ash etc. are finely ground solid materials that are used to replace a portion of the cement in a concrete mixture. The use of such by-products in concrete construction not only prevents these products from being land-filled and causing pollution but also enhances the properties of concrete in the fresh and hardened states. These supplementary cementitious materials by pozzolanic action react with hydration products to form calcium silicate hydrate(CSH) thus improving concrete quality and consequently reducing the cost of concrete production. One of such material is Corn Cob Ash (CCA). Research progress so far on the use of corn cob ash for cement replacement is presented in this paper. Review of literature was carried out to know the trend of its use in concrete, production methods and its effects on mechanical and durability properties of concrete.*

Key words: Concrete; corn cob ash (CCA); pozzolans; saw dust ash; supplementary cementitious materials.

1.0 INTRODUCTION

The overall concrete production cost depends largely on the availability and cost of its constituents like cement, aggregates and so on. Cement is the most utilized construction material, and the second most consumed commodity in the world after water. Cement is the most expensive constituent in the production of concrete and a little reduction per unit cost will largely reduce the overall construction cost. The production of cement is increasing yearly and a substantial percentage of the world's carbon dioxide emission is attributable to the cement industry. There is need to economize the use of cement as we cannot go on producing more and more of it because of the significant contribution to the environmental pollution, high cost of Portland cement and high consumption of natural resources like limestone e.t.c. Substantial energy and cost savings can be achieved when industrial and agricultural by-products are used as a partial replacement for the energy intensive Portland cement. The presence of mineral admixtures from agricultural waste is also known to impart significant improvement in workability and durability of concrete. The use of industrial and agricultural by-product in cement production is an environmental friendly way of disposal of large quantities of materials that would otherwise pollute land, water and air. One of the practical solutions to economize cement is to replace cement with industrial by-products and agricultural wastes as supplementary cementitious materials. Some of the waste products which possess pozzolanic properties and which have been studied for use in blended cements include fly ash, Silica fume, Volcanic ash, Rice husk ash, corn cob ash (CCA) e.t.c. Corn cob as the agricultural waste product obtained from maize; which is the most important cereal crop in sub-Saharan Africa. The United States is the worldwide leader in corn production, producing 40% of the worlds harvest (377.5 million metric tonnes) out of which 20% is exported (worldatlas; 2017). Nigeria was the second largest producer of maize in Africa and the thirteenth largest in the world in the year 2017 with 10.5 million metric tonnes while South Africa had the highest production of 12.5 million metric tonnes in Africa (indexmundi; 2017).

2.0 LITERATURE REVIEW

Kamau and Ahmed (2017) experimentally assessed the suitability of CCA as a partial cement replacement by substituting cement in concrete mixes with CCA at 0 %, 5 %, 7.5 %, 10 %, 15 % and 20 % steps. The researchers tested durability using the sulfate elongation test and reported that the highest compressive strength was observed at the 7.5 % replacement while higher replacement levels also showed impressive strengths suitable for structural works. They also observed that the sulfate elongation test results showed good performance for all CCA specimens in comparison to the control mix. The researchers concluded that findings showed good reproducibility and highlight the potential of CCA as an effective pozzolan.

Anjaneyulu (2017) evaluated the effects of partially replacing cement in concrete with waste Materials. Concrete cubes of size 150mm x 150mm x 150mm with different percentages of CCA and SDH to cement in the order of 0 %, 10 % and 15 % were cast. The concrete cubes were tested at the ages of 7, 14, 21, 28 and 56 days. The results from the experiment showed that the CCA and SDH were good pozzolans. The slump value decreased as the CCA and SDA contents increased indicating that concrete becomes less workable as the ashes content increased. The compressive strength of the concrete cubes increased as the days of curing increased and decreased with increasing ashes replacement. The highest compressive strength was 24.9 N/mm2 and 22.4 N/mm^2 at 56 days for 0 % and 10 % of CCA(M25) and 24.9 N/mm^2, 23.9 N/mm^2 for SDA (M25) respectively. The researcher concluded that the use of CCA and SDA as a partial replacement for cement in concrete, particularly in plain concrete works and non-load bearing structures, will improve waste to wealth initiative through only 10 % CCA and SDA replacement.

Priya et al (2017) studied the partial replacement of cement with CCA and coarse aggregate with steel slag. The CCA was used to replace cement partially in 5 % and 10 % ratio while steel slag was used to replace aggregate partially in 40 % and 50% ratio. They carried out compressive strength test, split tensile strength test and flexural strength test at ages of 7, 14 and 28 days. The researcher concluded that concrete acquires maximum increase in strength of concrete at 5 % replacement of cement by CCA and 40 % coarse aggregate replacement by steel slag.

Okwadha (2016) had done the research to investigate the Partial replacement of cement by plant solid waste ash in concrete Production. Chemical analysis of SDH, CCA, and sugarcane bagasse ash (SCBA) was performed to verify their pozzolanic activity for use in concrete manufacture. The sum of SiO2, Al2O3 and Fe2O3 was 75.39 %, 77.64 %, and 80.23 % for SDA, MCA, and SCBA respectively, indicating pozzolanic activity. Cement replacement was done at 0 %, 5 %, 10 %, 15 %, 20 %, 25 %, and 30 % by weight of cement. They observed that workability decreased as cement replacement increased, but increased as cement replacement increased for SCBA. Absorption and compressive strength of 150 mm x 150 mm x 150 mm cubes cured for 7, 14 and 28 days increased as cement replacement increased up to an optimum then decreased as a consequence of decreased formation of cementitious matrix. Optimum compressive strength was 26.30, 27.71, and 49.58 N/mm2 for SDA, MCA, and SCBA respectively at 10 % SDA and MCA, and 25 % SCBA. The researchers concluded that results have shown that the use of blended concrete can reduce environmental degradation attributed to disposal of plant wastes and raw materials mining for cement manufacture, and pollution from cement manufacturing process.

Dauda (2016) performed an experimental investigation on the performance of pozzolana cement elements produced from alternative raw materials with a view of using them in low-cost housing. The researcher investigated the possible use of CCA as a partial replacement of cement in sandcrete block production. 140 no. 450 mm x 150 mm × 225 mm solid sandcrete blocks of mix ratio 1:8 were cast, cured and crushed at 7, 14, 21, and 28 days. The CCA was replaced at 0 to 40 percent levels at 5% intervals. The maximum compressive strength of 2.10 N/mm^2 was recorded at 30 % replacement on the 28th day. After 12 months of exposure under northern savannah climatic conditions, the compressive strength remained stable or even increased with the weathering exposure. The maximum value of 2.10 N/mm^2 for the 30 % replacement level was found suitable and recommended for building construction having attained a 28-day compressive strength of more than 2.0 N/mm^2. The researchers later recommended that subsequent studies should be done on 0 - 40 % replacement of cement with CCA and in steps of 5 % while concretes with the presence of ash content should be allowed to cure for 90days, by which pozzolanic activity of ash would have been concluded.

Toryila (2016) conducted investigations on concrete produced by partial replacement of cement with CCA. CCA was obtained and used to replace cement partially in specified ratios of 5 %, 10 %, 15 %, 20 % and 25 % and concrete cubes were cast and cured in ages of 7, 14 and 28 days respectively whereas concrete beams were cast and cured for 28 days. Compressive strength test was carried out on the cubes and the flexural strength on beam. The researcher observed that the concrete strength decreased with increasing replacement with the CCA. The 28 days compressive strength for 5 % replacement was 28.78 N/mm^2, 10 % replacement was 26.22 N/mm^2, 15 % replacement was 22.33 N/mm^2, 20 % replacement was 20.27 N/mm^2 and 25 % replacement was 17.33 N/mm^2 respectively while its flexural strength for same age for 5 % replacement was 9.98 N/mm^2, 10 % replacement was 8.58 N/mm^2, 15 % replacement was 7.82 N/mm^2, 20 % replacement was 6.56 N/mm2 and 25 % replacement was 5.72 N/mm^2. The initial and final setting time of OPC - CCA at 10 % replacement was observed to be 168 minutes and 305 minutes respectively. The density of OPC - CCA was also observed to decrease with increasing CCA replacement. The 28-day density for 10 % CCA replacement for concrete cube was 2373.33 kg/m^3 and that of rectangular concrete beam was 2575 kg/m^3. The specific gravity of CCA was 2.55. They concluded that CCA can be used as partial replacement for cement in concrete production as well as for walls of building units and other mild construction works, and replacement should not exceed 10% as strength produced above this replacement level may not be adequate for strength requirements.

Kamau et al (2016) carried out investigations on the ability of CCA to be used as a supplementary cementitious material (SCM) by testing for pozzolanic properties and performance in sulfate environments. They carried out experiments by supplementing cement by weight in concrete mixes with CCA at 5 %, 7.5 %, 10 %, 15 %, 20 %, 25 % and 30 % steps and durability was tested using the sulfate elongation test. The results showed impressive compressive strengths that were suitable for structural applications. The researchers concluded from the sulfate elongation test that CCA supplemented concrete could be used in aggressive environments with an advantage. The compressive and tensile strengths and sulfate resistance tests showed good repeatability, with strengths capable of structural applications being observed over replacements of up to 20 % at 91 days. They thereafter reported that CCA can be used as a supplementary cementitious material to mitigate on the cost of cement and its impacts on the environment, thereby enhancing the sustainability of cement.

Suwanmaneechot et al (2015) experimentally investigated the development of waste CCA as supplementary cement replacement materials. They focused on the effects of heat treatment on chemical composition, physical properties and engineering properties of CCA. The results suggested that CCA that was heat treated at 600°C for 4 h showed percentage of SiO2 + Al2O3 + Fe2O3 around 72 %, which can be classified as Class N calcined natural pozzolan, as prescribed by ASTM C618. The X-ray diffraction patterns indicated that the amorphous silica phase increased with increasing calcining temperatures. The water requirement, initial setting time and final setting time of specimens increased with increasing replacement percentage of raw or treated CCA. The cubes which used 20 % of treated CCA replaced cement showed 103 % of the 28 days compressive strength as compared to reference samples. The researchers observed that CCA that was treated at 600 °C for 4 h samples showed slightly higher effectiveness for improving the splitting tensile strength and compressive strength of concrete when compared to the untreated CCA.

Oluborode and Olofintuyi (2015) investigated the characteristics of CCA in uncompacted concrete. Varied percentage of corn-cob ash at 0 %, 10 %, 20 %, and 30 % replaced cement. They carried out tests to determine the chemical composition of CCA in comparison with ordinary portland cement (OPC) and mechanical test such as specific gravity test, absorption test of aggregate, particle size distribution test of aggregate. Compressive strength of hardened cured concrete cubes at 7days, 21 days and 28 days were tested. The researchers noted that at 30 % CCA, the compressive strength was 18.44 N/mm2. They thereafter concluded that up to 30 % replacement of cement with CCA is feasible. The researchers later recommended that subsequent studies should be done on 0 - 50 % replacement of cement with CCA and in steps of 5 %.

Akinwumi and Aidomojie (2015) carried out an experiment on the engineering properties of lateritic soil stabilized with cement - CCA to ascertain its suitability for use as a pavement layer material. Series of specific gravity, consistency limits, compaction, California bearing ratio (CBR) and permeability tests, considering three CCA blends and four CCA contents, varying from 0 to 12 %, were carried out. The results showed that the addition of CCA to the soil generally reduced its plasticity, swell potential and permeability; and increased its strength. The researcher concluded that CCA - stabilization, aside being more economical and environment - friendly than cement - stabilization, improved the geotechnical properties of the soil for pavement layer material application.

Antonio et al (2014) evaluated the benefits of replacing Ordinary Portland Cement (OPC) with CCA blended cements. They carried out an experiment to designate an appropriate percentage replacement of CCA that would comply with specific standards of cement production. The experimental plan was designed to analyze compressive strength, workability and thermal performance of various CCA blended cements. The researchers concluded that up to 10 % CCA replacement could be used in cement production without compromising the structural integrity of OPC and that the compressive strength and workability of the resulting concrete could be improved when CCA is added to the mixtures. Furthermore, they recorded that the introduction of 10 % CCA can lead to significant reduction in thermal conductivity of the mixture.

Mujedu et al (2014) studied the workability and compressive strength properties of varying percentage of CCA and SDH cement concrete. They also carried out Slump test to check the effect of combination of CCA and SDA on the workability of fresh concrete while also casting Concrete cubes with different percentages by weight of combination of CCA and SDA to Portland cement in the order of 0 %, 10 %, 20 %, 30 %, 40 % and 50 %. The concrete cubes were tested at the ages of 3, 7, 14, 21, 28 and 56 days. They concluded that the combination of CCA and SDA were a good pozzolan with combined SiO2, Al2O3 and Fe2O3 of 76.67 % and that the slump value decreased as the combination of CCA and SDA contents increased indicating that concrete becomes less workable as the ashes content increased. They noted that the compressive strength of the concrete cubes increased as the days of curing increased and decreased with increasing ashes replacement. The compressive strength of concrete cubes with the combination of CCA and SDA was lower at early stages but improves significantly up to 56 days. The highest compressive strength was 25.52 N/mm^2 and 23.99 N/mm^2 at 56 days for 0 % and 10 % combination of CCA and SDA respectively. The researchers concluded that the use of combination of CCA and SDA as a partial replacement for cement in concrete, particularly in plain concrete works and non – load bearing structures, will improve waste to wealth initiative though only 10 % CCA – SDA replacement is adequate to enjoy maximum benefit of strength gain. The researchers later recommended that subsequent studies should be done on 0 - 50 % replacement of cement with CCA and in steps of 5 % while concretes with the presence of ash content should be allowed to cure for 120 days, by which pozzolanic activity of ash would have been concluded.

Jimoh and Apampa (2014) reports the investigation of CCA as a pozzolan and a stabilizing agent for lateritic soils in road pavement construction. Reddish brown silty clayey sand material locally recognized as laterite was mixed with CCA in varying percentages of 0 %, 1.5 %, 3 %, 4.5 %, 6 % and 7.5 % and the influence of CCA on the soil was determined for Liquid Limit, Plastic Limit, Compaction Characteristics, CBR and the Unconfined Compression Test. These tests were repeated on laterite – CCA - cement mix and laterite - cement mix respectively in order to detect any pozzolanicity in CCA when it combines with Portland cement and to compare results with a known soil stabilizing agent. The result showed a similarity in the compaction characteristics of soil - cement, soil - CCA and soil – CCA - cement, in that with increasing addition of binder from 1.5 % to 7.5 %, Maximum Dry Density progressively declined while the OMC steadily increased. In terms of the strength parameters, the maximum positive impact was observed at 1.5 % CCA addition for soil - CCA with a CBR value of 84 % and a UCS value of 1.0 MN/m^2, compared with the control values of 65 % and 0.4 MN/m^2 respectively. For the soil – CCA - cement mix, the strength parameters CBR and UCS continued to increase with increasing binder addition within the tested range for the ratios 1 : 2 and 1 : 1 and 2 : 1 CCA : cement. The researcher observed that the results from the soil - CCA -

cement mix, indicate the pozzolanicity of CCA in that UCS values were higher by at least 14 % for the 1 : 1 ratio, than was attained with the addition of only the corresponding quantity of cement.

Ettu et al (2013) researched on the Strength of Binary Blended Cement Composites Containing CCA. 105 concrete cubes and 105 sandcrete cubes of 150 mm x 150 mm x 150 mm were produced at percentage OPC replacement with CCA of 5 %, 10 %, 15 %, 20 %, and 25 % and crushed to obtain their compressive strengths at 3, 7, 14, 21, 28, 50, and 90 days of curing. The 3 - 28-day compressive strength values of OPC - CCA binary blended cement concrete were found to be much lower than the control values; the 50-day strengths were comparable to the control values; while the 90-day strengths were higher than the control values especially at 5 – 15 % replacements of OPC with CCA, ranging from 24.00 N/mm2 for 15 % replacement of OPC to 27.00 N/mm2 for 5 % replacement of OPC compared with the control value of 23.60 N/mm^2. This same trend was observed for OPC - CCA binary blended cement sandcrete. The variation in density was not significant. Mathematical models were developed for predicting compressive strengths of OPC - CCA binary blended cement composites using polynomial regression analysis. The model values of compressive strengths obtained from the various model equations were found to be either exactly the same as those of the equivalent laboratory values or very close to them, with differences ranging from 0 to 0.3 N/mm^2. The researcher concluded that OPC - CCA binary blended cement composites could be good for civil engineering works and the developed model equations can be used to estimate their strengths for various curing ages and percentage OPC replacement with CCA.

Olafusi and Olutoge (2012) carried out a study on the Strength Properties of CCA Concrete. Physical and mechanical properties of varying percentage of CCA cement concrete and 100 % cement concrete of mix 1 : 2 : 4 and 0.5 water - cement ratios were examined and compared. A total of 72 concrete cubes of size 150 × 150 × 150 mm^3 and 12 concrete cylinders of size 100mm (diameter) x 200mm (height) with different percentages by volume of CCA to Portland cement in the order 0 : 100, 10 : 90 and 20 : 80 were cast, tested and their physical and mechanical properties determined. A high strength (35MPa) concrete was further designed using CCA as a partial replacement for cement with a total of 32 concrete cubes (16 samples each for 0 % and 10 % partial replacements) and 8 concrete cylinders (4 samples each of 0 % and 10 % partial replacements). The specific gravity of the CCA was obtained as 1.15, while the mechanical properties which included compressive strength tests showed that 10 % of the CCA in replacement for cement was quite satisfactory with no compromise in compressive strength requirements for concrete mix ratios 1 : 2 : 4 at 7 days, but did not meet the standard strength at 14, 21 and 28 days. The 20 % CCA replacement for cement did not meet the satisfactory strength requirements at all. While the split tensile test revealed that concrete tensile strength is about 11 - 12 times lower than its compressive strength. The high strength concrete designed was adequate in compressive and split tensile strength requirement, but did not reach the designed compressive strength of 35 MPa at 28 days. The researchers concluded that the use of CCA as a partial replacement for cement in concrete, particularly in plain concrete works and non-load bearing structures; will enhance waste to wealth initiative. They also affirmed that CCA could be used as a partial replacement for cement in high strength concrete, but the CCA concrete would take longer time to achieve its designed strength and the CCA concrete would require water / cement ratio less than 0.40. Hence, they endorsed the use of superplasticizers is required to enhance workability. The researchers then recommended that subsequent studies should be done on 0 - 40 % replacement of cement with CCA and in steps of 5 % while concretes with the presence of ash content should be allowed to cure for 90 days, by which pozzolanic activity of ash would have been concluded.

Adesanya and Raheem (2010) investigated the workability and compressive strength characteristics of CCA blended cement concrete. They also assessed the development of CCA blended cement. The researchers used CCA as a pozzolan and determined the physical and chemical properties of concrete from blended cement. Corn cobs were ground and burnt in a furnace using charcoal as a fuel at 650 oC. The CCA was mixed with Portland cement and the mixture contained 0, 2, 4, 6, 8, 10, 15, 20 and 25 % CCA, by weight. They concluded that all CCA - blended cements had higher setting times than Portland cement and that they were suitable for situations where a low rate of heat development is required, such as in mass concreting and that CCA - blended cement was comparable to low heat cement. The researchers concluded that at levels lower than 15 % substitution, CCA was a good pozzolan for blended cement. They also tested the workability and compressive strength of nine mixtures of CCA - blended cement containing 0 to 25 % CCA in the total mass. Based on structural load criteria, they recorded an optimum blend that contained 8 % CCA. The durability of concrete made with CCA - blended cement was similarly investigated with respect to permeability and acid resistance. The observation was that the CCA-blended cement reduced water absorption in concrete and resistance to chemical attack (HCl and H2SO4) was improved with the addition of up to 15 % CCA.

Ikponmwosa et al (2009) experimentally evaluated the Strength Characteristics of laterized concrete with CCA. Laterized concrete specimen of 25 % laterite and 75 % sharp sand were made by blending cement with CCA at 0 to 40 % in steps of 10 %. A concrete mix ratio of 1 : 2 : 4 was used to cast 54 cubes of 150 x 150 x 150 mm size and 54 beams of dimension 750 x 150 x 150 mm. The results showed that the consistency and setting time of cement increased as the percentage replacement of cement with CCA increased while the workability and density of concrete decreased as the percentage of CCA increased. The researcher also observed that there was a decrease in compressive strength when laterite was introduced to the concrete from 25.04 to 22.96 N/mm^2 after 28 days and a continual reduction in strength when CCA was further added from 10 % to 40 % at steps of 10 %. They noted that the beam specimens exhibited majorly shear failure with visible diagonal cracks extending from support points to the load points. The corresponding central deflection in beams, due to two points loading, increased as the laterite was added to the concrete mix but reduced and almost approaching that of the control as 10 % CCA was added. The deflection then increased as the CCA content further increased to 20 %, 30 % and 40 % in the mix. They also noted that the deflection of all percentage replacement including 40 % CCA is less than the standard recommended maximum deflection of the beam. The researcher reported that optimal flexural strength occurred with 10 % CCA content.

Binici et al (2008) had concluded in a research that an increase in ash content caused a significant increase in the sodium sulphate resistance of the concretes. The researcher reported that microscopic analysis showed that CCA as an additive had a more condensed physical structure than Portland cement, making it more resistant to sulphate attack.

CONCLUSION

After evaluating the various researches relating to partial replacement of Cement with Corn Cob Ash by various authors, the following conclusions are drawn:

1. CCA is pozzolanic and is consequently suitable for concrete production.
2. Utilization of CCA for production of concrete will reduce overall concrete cost and also reduce the amount of waste in the environment.
3. Strength of concrete rises with curing age and declines as percentage replacement of CCA increases.
4. Consistency and setting time of cement rises with increasing CCA percentage.
5. CCA Workability declines as the proportion of CCA increases in the concrete mix.
6. Water requirement rises as the proportion of CCA increases in the concrete mix.
7. Weight of concrete reduces with the use of CCA, thus creating light weight concrete.
8. Design strengths of CCA concretes is not attained at 28days due to its pozzolanic activities.
9. CCA concrete can be used for wide-ranging concrete works like mass concrete, floor screed, and mortar, where strength is of less importance as strength of CCA concrete is lesser than that of the control.
10. CCA concrete density declines with increasing CCA percentage.
11. It is recommended that subsequent studies should be done on 0 - 50 % replacement of cement with CCA and in steps of 5 % while concretes with the presence of ash content should be allowed to cure for 120 days, by which pozzolanic activity of ash would have been concluded.

REFERENCES

1. A A Mohd, S B Olugbenga, and A A Mohd. Adsorption Studies of Remazol Brilliant Blue R Dye on Activated Carbon Prepared from Corncob. American Journal of Modern Chemical Engineering. 2014; 1, 1-12.
2. A Dauda. Exploring the Potential of Alternative Pozzolona Cement for the Northern Savannah Ecological Zone in Ghana. American Journal of Civil Engineering. 2016; 4(3), 74-79.
3. A M Mohamed, K M Dinesh, C J Milan and G Vani. Replacement of Cement using Eggshell Powder. SSRG International Journal of Civil Engineering (SSRG-IJCE). 2016; 3(3), 1-2.
4. A S Alkali. 2016, Optimization of Activated Carbon Preparation from Corncob Wastewater Treatment, Ph. D. Dissertation. Department of Chemical Engineering, Faculty of Engineering Ahmadu Bello University, Zaria, Nigeria
5. D A Adesanya and A A Raheem. A study of the permeability and acid attack of corn cob ash blended cements. Construction and Building Materials. 2010; 24, 403 – 409.
6. E E Ikponmwosa, M A Salau and W B Kaigama. Evaluation of Strength Characteristics of Laterized Concrete with Corn Cob Ash (CCA) Blended Cement. IOP Conf. Series: Materials Science and Engineering. 2009; 96, 1-9.
7. F Faleschini,, P De Marzi, and C Pellegrino. Recycled concrete containing EAF slag: environmental assessment through LCA. European Journal of Environmental and Civil Engineering. 2014; 18, 1009-1024.
8. G D O Okwadha. Partial replacement of cement by plant solid waste ash in concrete Production. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE). 2016; 13(5), 35-10.
9. H Binici, F Yucegok, O Aksogan and H Kaplan. Effect of corncob, wheat straw, and plane leaf ashes as mineral admixtures on concrete durability. Journal of Materials in Civil Engineering. 2008; 20 (7), 478-483.
10. H T Le and H M Ludwig. Effect of rice husk ash and other mineral admixtures on properties of self-compacting high-performance concrete. Materials & Design. 2016; 89, 156-166.
11. I I Akinwumi and O I Aidomojie. Effect of Corncob ash on the geotechnical properties of Lateritic soil stabilized with Portland cement. International Journal of Geomatics and Geosciences. 2015; 5, 375-392.
12. I O Obilade. Use of Saw Dust Ash as Partial Replacement for Cement in Concrete. International Journal of Engineering Science Invention. 2014; 3(8), 36-40.
13. Indexmundi, Available at: https://www.indexmundi.com/agriculture/?commodity=corn, accessed February 2018.
14. J Kamau and A Ahmed. Suitability of Maize Cob Ash as a Partial Cement Replacement. Juniper Online Journal Material Science. 2017; 2(5), 001-003.
15. J Kamau, A Ahmed, P Hirst and J Kangwa. Suitability of Corncob Ash as a Supplementary Cementitious Material. International Journal of Materials Science and Engineering. 2016; 4, 215-228.
16. K A Mujedu, S A Adebara, I O Lamidi. The Use of Corn Cob Ash and Saw Dust Ash as Cement Replacement in Concrete Works. The International Journal of Engineering and Science (IJES). 2014; 4, 22-28.
17. K Anjaneyulu. Partial replacement of cement concrete by waste Materials. International Journal of Engineering Development and Research. 2017; 5(2), 1374-1383.
18. K D Oluborode and I O Olofintuyi. Strength Evaluation of Corn cob ash in a blended Portland cement. International Journal of Engineering and Innovative Technology (IJEIT). 2015; 4, 14-17.
19. K Saini, V Chaudhary, A Bisnohi, H Agarwal, M Ram, S Saraswat. Effect on strength properties of concrete by using waste wood powder as partial replacement of cement. SSRG International Journal of Civil Engineering (SSRG-IJCE). 2016; 3(5), 172-176.
20. L O Ettu, U C Anya, J I Arimanwa, L Anyaogu, and K C Nwachukwu. Strength of Binary Blended Cement Composites Containing Corn Cob Ash, International Journal of Engineering Research and Development. 2013; 6(10), 77-82.
21. M A Mohammed, G Babagana and K H Bitrus. Production and Characterization of Activated Carbon from Groundnut Shell Sourced In Maiduguri. Columbia Journal of Life Science. 2015; 17 (1), 18-24.
22. M O Mulwa, T O J Karanja and M J Wachira. Effect of sulphate ions in mixing water on cement mortar performance. Chemistry Department, Kenyatta University, Kenya. School of Pure and Applied Sciences, Embu University College, Kenya., IOSR Journal of

Applied Chemistry (IOSR-JAC). 2016; 9, 11-15.

23. S Olafusi and F A Olutoge. Strength Properties of Corn Cob Ash Concrete. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS). 2012; 3(2), 297-301.
24. P Antonio, Y Ryan, F Ellie and A Taher. Investigating Effects of Introduction of Corncob Ash into Portland Cements Concrete: Mechanical and Thermal Properties. American Journal of Engineering and Applied Sciences. 2014; 7 (1), 137-148.
25. P Suwanmaneechot, T Nochaiya and P Julphunthong. Improvement, characterization and use of waste corn cob ash in cement-based materials. IOP Conference Series: Materials Science and Engineering. 2015; 103(1).
26. S Kandasamy and M H Shehata. Durability of ternary blends containing high calcium fly ash and slag against sodium sulphate attack. Construction and Building Materials. 2014; 53, 267-272.
27. S Priya, R Dhanasekar, P Vijayalakshmi, A Siva and P Vignesh. Experimental Investigation on Partially Replacement of Cement, Coarse Aggregate by Corn Cob Ash and Steel Slag. International Journal for Innovative Research in Science & Technology. 2017; 3(10), 209-214.
28. T M Toryila. Partial Replacement of Cement with Corn Cob Ash. International Journal for Innovative Research in Multidisciplinary Field. 2016; 2(7), 159-169.
29. Worldatlas, Available at: https://www.worldatlas.com/articles/world-leaders-in-corn-maize-production-by-country.html, accessed February 2018.
30. Y A Jimoh and O A Apampa. An Evaluation of the Influence of Corn Cob Ash on the Strength Parameters of Lateritic Soils. Civil and Environmental Research. 2014, 6(5), 1-10.