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Suitability of Corn Cob Ash as Partial Replacement for Cement in Concrete

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Abstract— This research used corn cob ash (CCA) as a pozzolan in a bid to promote green and sustainable construction while also reducing the overall cost of concrete production. This study investigates the mechanical performance of corn cob ash concrete. It examined the density and compressive strength of CCA - cement concrete using a 1: 2: 4 mix ratio and a water - cement ratio of 0.5. Cubes of 150 mm x 150 mm x 150 mm dimension with varying percentages by weight of CCA to cement combination in the order of 0 %, 5 %, 10 %, 20 % and 30 % were cast. Tests on concrete were carried out at ages 28, 56, 90 and 120 days. It was observed that concrete produced with up to 20 % CCA – cement replacement can be used for construction purposes.

Index Terms— Cement, compressive strength, concrete, construction, corn cob ash (CCA), density, pozzolan.

1 Introduction

In a bid to secure adequate housing for the world's teeming population, the need for affordable construction materials cannot be overemphasised. Cost of construction materials continues to increase as the bulk of the populace persistently fall below the poverty line. Therefore, there is a need to explore cheap and locally available materials for construction purposes. A decrease in the cost of construction materials can effectively reduce the overall cost of building construction as cost of materials makes up two - thirds of total building cost [1]. Consequently, the centre of focus in this research work is the ordinary portland cement which is one of the most commonly utilised construction materials worldwide. Cement is the second most utilised commodity worldwide after water; it is also the most used construction material [2]. However, it is the most expensive component of concrete production. Therefore, a small reduction of cement per unit cost will significantly decrease the total cost of building construction. Cement production is increasing yearly by 3 % [3], and the universal cement industry makes about 3.3 billion tonnes of cement per annum [4]. Even as this figure rises annually, The production of each ton of cement emits about one ton of carbon dioxide [5]. In other words, it can be inferred that approximately 7 % of the earth's carbon dioxide emission is from the portland cement industry [3]. A number of ready available bye - products and wastes which contain pozzolanic characteristics and have been researched for use in cement concrete comprise CCA which is obtained from corn cob[1], fly ash, known as pulverized fuel - ash [6], rice husk ash which is obtained from rice husk [7], sugar cane bagasse ash which is obtained from sugar cane [8], granite powder [9], metakaolin [10], egg shell powder [11], groundnut shell [12], sawdust ash [13], plant solid waste ash [14], steel slag [15] and waste wood powder [16]. Corn cob was defined by Adesanya and Raheem [1] as the agricultural waste product gotten from corn which is by far the most indispensable cereal crop in sub-Saharan Africa. According to 2007 FAO estimates [17]; 158 million hectares of maize are harvested worldwide. Africa harvests 29 million hectares, with Nigeria, the largest producer in SSA harvesting 3 %, followed by Tanzania. Global production of maize is 785 million tonnes, with the largest producer, the United States, producing 42 %. Africa produces 6.5 %, and the most significant African producer is Nigeria with nearly 8 million tonnes, followed by South Africa [17]. Nigeria was the thirteenth largest producer of maize in the world in the year 2017, with 10.5 million metric tonnes [18]. The United States is the worldwide leader in corn production, and it produces 377.5 million metric tonnes out of which 20 % is exported [19].

2 Material And Methods

2.1 Corn Cob Ash

The corn cobs used for this study were obtained in dry form from Ejiba town in Kogi State. They were sundried for one week and later grinded to approximately 4.0 mm diameter to enhance adequate combustion. The cobs were then burnt at the furnace of SHEDA Science and Technology complex (SHESCO), Kwali, F.C.T. into ash at a maximum temperature of 650 ^{o}C. The burnt ashes were then sieved through British Standard sieve of 75 µm. The portion passing through the sieve had the required degree of fineness of 63 µm and below while the residue was discarded. The CCA resulting from the combustion was used in the experiment. Some quantity of CCA was taken to the laboratory and tests were performed on the sample to know the elemental content and other oxide composition using X-ray fluorescence (XRF). The analysis was carried out at the Nigerian Geological Survey Agency, National Geosciences Research Laboratory (NGRL), Kaduna State.

2.2 Materials

The coarse aggregate used consists of granite obtained from a quarry in Abuja, Nigeria, and it was clean, free of dirt and dust. Fine aggregate used consisted of stone dust which was obtained from a quarry in Abuja. It was clean, free of clay, dirt and any organic or chemical matter. The type of cement used in this study is the Dangote brand of Ordinary Portland cement. It was sourced from Abuja, Nigeria. It is type 1 cement as defined by [54]. Water used in this study for mixing and curing concrete was clean, colourless fresh water from an approved source (tap water from the Faculty of Engineering, University of Abuja, Federal Capital Territory). It was free from visible impurities and good for drinking.

2.3 Chemical composition of corn cob ash (CCA)

X - ray fluorescence machine was employed in the analysis of the ash to know the elemental and oxide composition of CCA at the Nigerian Geological Survey Agency, National Geosciences Research Laboratory (NGRL), Kaduna State in accordance with [42].

2.4 Fresh concrete

The percentage replacements by weight of ordinary portland cement (OPC) by CCA was 0 %, 5 %, 10 %, 20 % and 30 % and a water / cement ratio of 0.5. A concrete mixer was used to mix the materials by methodically stirring the cement, coarse aggregates, fine aggregates, water and CCA into a homogenous mass. The workability of the various mixes was tested using the slump test apparatus and described in [48]. Workability was also tested using the compacting factor test using the compacting. Setting time, fineness, consistency and soundness tests were carried out in accordance with [55].

2.5 Hardened Concrete

Three concrete specimens, each with size 150 mm x 150 mm x 150 mm were cast for the experiment. The concrete cubes were cautiously demoulded 24 hours after casting and cured in a concrete curing tank containing portable water at a temperature of 18 °C to 23 °C. The samples were cured at the laboratory of Faculty of Engineering, University of Abuja. Before crushing, the samples were carried out of the curing tank and kept for approximately 25 minutes for most of the water to wipe off. The cubes were later taken to the digital crushing machine after being weighed on a weighing balance. Then CCA / concrete cubes were crushed to determine their compressive strength at ages 28, 56, 90 and 120 days. The machine automatically stopped every time failure occurred, and at that juncture, it displayed the failure load and printed the result. The density of the specimens was equally calculated. The compressive strength value was taken as the average for three concrete cubes.

3 Result

3.1 Chemical composition of corn cob ash (CCA)

Table 1: Shows a distinct comparison between the percentage elemental and oxide composition of both CCA and OPC. From the test result, the composition of silicon dioxide is 62.2 % which is above the 25 % range stated in [56]. Consequently, CCA is classified as a class F pozzolana using the [42] for pozzolanic classification. The summation of the composition of Silicon Oxide, Aluminium Oxide and Iron Oxide was more than the 70 % minimum specification for pozzolanas [42].

Table 1: Comparison of Oxide Composition of CCA and Cement

Constituents	Percentage Composition of CCA	Average Percentage Composition of Cement
Aluminum Oxide (Al_2O_3)	17.9	6
Silicon dioxide (SiO_2)	62.2	20
Potassium Oxide (K_2O_3)	2.61	-
Calcium Oxide (CaO)	2.96	63
Manganese Oxide (Mn_2O_3)	1.69	-
Iron Oxide (Fe_2O_3)	9.13	3
Copper Oxide (CuO)	0.22	-
Titanium Oxide (TiO_2)	0.49	-
Potassium Oxide (K_2O_3)	2.13	-

3.2 Density

Table 2: Shows the density of the cubes. D1 is the density of test sample 1, D2 is the density of test sample 2, D3 is the density of test sample 3 and DA is the average density of the three test samples. The result shows that density decreased as the percentage of CCA increased in the specimens. This may be because OPC has a higher specific gravity (3.15) than CCA (2.15). In this scenario, bulk density decreases as the percentage of CCA increases.

Table 2: Density of concrete cubes

CCA Content		Density of cubes kg / m^3			
		28 days	56 days	90 days	120 days
0 % CCA	D1	2603	2672	2666	2602
	D2	2594	2516	2691	2711
	D3	2582	2768	2674	2718
	DA	**2593**	**2652**	**2677**	**2677**
5 % CCA	D1	2545	2590	2499	2593
	D2	2584	2562	2589	2603
	D3	2608	2408	2595	2562
	DA	**2579**	**2520**	**2561**	**2586**
10 % CCA	D1	2526	2497	2331	2513
	D2	2551	2534	2529	2595
	D3	2522	2481	2703	2488
	DA	**2533**	**2504**	**2521**	**2532**
20 % CCA	D1	2602	2504	2457	2575
	D2	2487	2448	2589	2406
	D3	2468	2485	2370	2471
	DA	**2519**	**2479**	**2472**	**2484**
30% CCA	D1	2305	2539	2489	2510
	D2	2458	2337	2561	2398
	D3	2659	2474	2282	2436
	DA	**2474**	**2450**	**2444**	**2448**

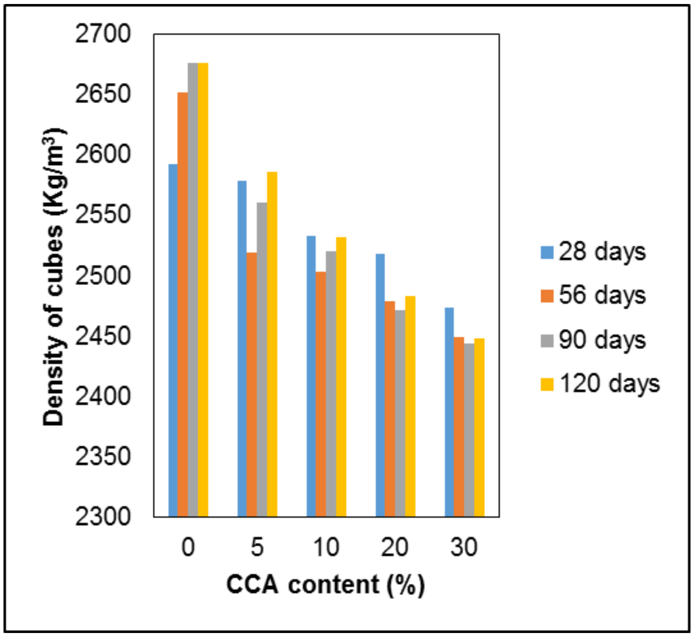

Figure 1: Average density of cubes versus CCA content

3.3 Compressive strength

Table 3: Shows the compressive strength of CCA / cement concrete at 28, 56, 90 and 120 days, where Fcu_1 is the compressive strength of test sample 1, Fcu_2 is the compressive strength of test sample 2, Fcu_3 is the compressive strength of test sample 3 and Fcu_A is the average compressive strength of the three test samples. From the results, it can be seen that cubes with 0 % CCA had the highest compressive strength because the cement proportion was the highest. In addition, the results showed that for the same age of concrete, compressive strength decreased as the percentage of CCA / OPC content increased. Furthermore, the rate of compressive strength increase with age is rapid within the first twenty - eight days. The rate subsequently increased gradually at a diminishing rate until 90 days after which it slightly increased again till 120 days. Also, results obtained from this study show that specimens containing up to 20 % CCA had an average compressive strength of 20.1 N / mm^2 at 28 days and 27.79 N / mm^2 at 120 days. Consequently, it can be inferred that concrete produced with up to 20 % CCA / cement replacement can be utilised for construction purposes.

Table 3: Compressive strength of test samples

CCA Content		Compressive Strength (N/mm^2)			
		28days	56days	90days	120days
0% CCA	Fcu_1	23.8	30.7	32.9	38.2
	Fcu_2	27.6	31.3	34.6	36.3
	Fcu_3	26.9	29.2	32.1	41.9
	Fcu_A	**26.1**	**30.4**	**33.2**	**38.8**
5% CCA	Fcu_1	27	25.8	30	33.7
	Fcu_2	27.7	26.9	28.8	31.6
	Fcu_3	17.9	30.4	30	35.8
	Fcu_A	**24.2**	**27.7**	**29.6**	**33.7**
10% CCA	Fcu_1	23.33	22.4	24.2	27
	Fcu_2	23.8	23.8	26.1	29.4
	Fcu_3	19.47	25.5	25.3	31.8
	Fcu_A	**22.2**	**23.9**	**25.2**	**29.4**
20% CCA	Fcu_1	22. 4	22.4	24.9	27.8
	Fcu_2	20.3	25.8	20.6	25.3
	Fcu_3	17.6	18.4	24.7	30.3
	Fcu_A	**20.1**	**22.2**	**23.4**	**27.8**
30% CCA	Fcu_1	14.4	16.2	18.1	19.2
	Fcu_2	16.7	19.1	16.4	19.5
	Fcu_3	13.6	13.3	17.7	19.8
	Fcu_A	**14.9**	**16.2**	**17.4**	**19.5**

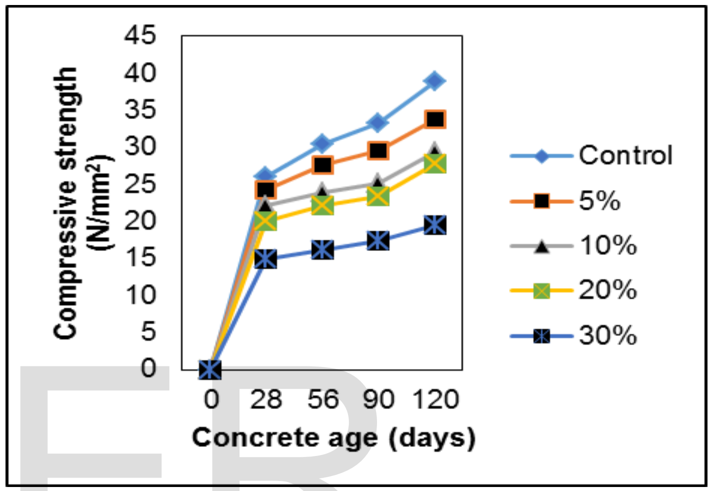

Figure 2: Average compressive Strength versus Concrete Age

4 Conclusion

After evaluating the results of this study, the following conclusions were drawn:

1. CCA is pozzolanic as it has a combined (SiO_2 + Al_2O_3 + Fe_2O_3) of above 70 %. It is classified as a pozzolan in class F according to [42].
2. Compressive strength of CCA / concrete is not fully achieved at 28 days but increases till 120 days due to the pozzolanic activity of CCA.
3. Compressive strength and density of concrete decrease with increasing CCA percentage.
4. Concrete produced with up to 20 % CCA / cement replacement can be used for diverse concrete works where strength is of less significance (like mass concreting and screeding) as CCA / cement concrete has a lower strength than portland cement concrete.
5. The use of CCA for concrete production will decrease overall cost of concrete and reduce the amount of waste in the environment.

Recommendations

1. Additional studies should be embarked on by allowing CCA / cement concrete to cure for 360 days in order to find out exactly when pozzolanic activity of ash would be concluded.

2. Further studies should be carried out on the utilization of superplasticizers to enhance the strength properties of CCA / cement concrete.

REFERENCES

[1]. 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, vol. 24, pp. 403 – 409, 2011.
[2]. J. Kamau, A. Ahmed, P. Hirst, J. Kangwa, "Suitability of Corncob Ash as a Supplementary Cementitious Material," International Journal of Materials Science and Engineering, vol. 4, pp. 215-228, 2016.
[3]. S. O. Olafusi and F. A. Olutoge, "Strength Properties of Corn Cob Ash Concrete," Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) vol. 3(2), pp. 297-301, 2012.
[4]. J. Zhang, "Energy, environmental and greenhouse gas effects of using alternative fuels in cement production," M.Sc. dissertation, Dept. Env. Eng., Columbia Univ., 2013.
[5]. R. McCaffrey, "Climate change and the cement industry," Global Cement and Lime Magazine, vol. Environmental special issue, pp. 15-19, 2002.
[6]. 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, vol. 53, pp. 267-272, 2014.
[7]. 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, vol. 89, pp. 156-166, 2016.
[8]. R. Vignesh; V. Hemalatha; S. Jeyanthi Saranya; J. K. Ronnietta Kennedy, "Experimental Study on Partial Replacement of Cement by Sugarcane Bagasse Ash (SCBA)," International Journal of Engineering Research and Modern Education, Special Issue, pp. 255-259, 2017.
[9]. P. Saxena, R. Sharma, R. K. Shakya, N. K. Singh, "A Comparative Study on Partial Replacement of Cement With Fly ash & Granite Powder," IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), vol. 13(3), pp. 86-89, 2016
[10]. A. V. S. Kumar and R. Krishna, "A Study on Strength of Concrete with Partial Replacement of Cement with Quarry Dust and Metakaolin," 2014.
[11]. A. M. Mohamed, K. M. Dinesh, C. J. Milan, G. Vani, "Replacement of Cement using Eggshell Powder," SSRG International Journal of Civil Engineering (SSRG-IJCE), vol. 3(3), pp. 1-2, 2016.
[12]. 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, vol. 17 (1), pp. 18-24, 2015.
[13]. I. O. Obilade, "Use of Saw Dust Ash as Partial Replacement for Cement in Concrete," International Journal of Engineering Science Invention, vol. 3(8), pp. 36-40, 2014.
[14]. 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), vol. 13(5), pp. 35-10, 2016.
[15]. S. Priya, R. Dhanasekar, P. Vijayalakshmi, A. Siva, 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, vol. 3(10), pp. 209-214, 2017.
[16]. 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), vol. 3(5), pp. 172-176, 2016.
[17]. IITA Records, [Online]. Available: https://www.iita.org/cropsnew/maize/ [Accessed Aug. 18, 2019].
[18]. Index Mundi, 2019. Available: https://www.indexmundi.com/agriculture/? commodity= corn [Accessed Aug. 18, 2019].
[19]. World facts, para. 11, 2017. [Online]. Available: https://www.worldatlas.com/articles/world-leaders-in-corn-maize-production-by-country.html [Accessed Aug. 18, 2019].
[20]. L. Turanli, B. Uzal, F. Bektas, "Effect of material characteristics on the properties of blended cements containing high volumes of natural pozzolans," Cement Concrete Res, vol. 34, pp. 77–82, 2004.
[21]. 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, vol. 103(1), 2015.
[22]. C. A. Taiwo, "Properties of Corn Cob Ash Concrete," Ph.D dissertation, Dept. Civil. Eng., Ahmadu Bello Univ., Zaria, KD, 2012.
[23]. 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, vol. 5, pp. 375-392, 2015.
[24]. T. M. Toryila, "Partial Replacement of Cement with Corn Cob Ash," International Journal for Innovative Research in Multidisciplinary Field, vol. 2(7), pp. 159-169, 2016.
[25]. 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, vol. 7 (1), pp. 137-148, 2014.
[26]. 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), vol. 4, pp. 22-28, 2014.
[27]. 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), vol. 4, pp. 14-17, 2015.
[28]. J. Kamau and A. Ahmed, "Suitability of Maize Cob Ash As A Partial Cement Replacement," Juniper Online Journal Material Science, vol. 2(5), pp. 001-003, 2017.
[29]. K. Anjaneyulu, "Partial replacement of cement concrete by waste Materials," International Journal of Engineering Development and Research, vol. 5(2), pp. 1374-1383, 2017.
[30]. J. D. Bapat, Mineral admixtures in cement and concrete, CRC Press, 2012
[31]. M. Shetty, Concrete technology: theory and practice, 2005.
[32]. K. J. Rao, M. A. Mujeeb, and M. Sastri, "Behavior of ternary blended concrete with fly ash and silica fume," IUP Journal of Structural Engineering, vol. 7, pp. 25, 2014.
[33]. X. M. Zhou, J. R. Slater, S. E. Wavell, and O. Oladiran, "Effects of PFA and GGBS on Early Ages Engineering Properties of Portland Cement Systems," Journal of Advanced Concrete Technology, vol. 10, pp. 74-85, 2012.
[34]. F. F. Udoeyo and S. A. Abubakar, "Maize-cob ash as filler in concrete," Journal of materials in civil engineering, vol. 15, pp. 205-208, 2003.
[35]. T. Chanadee and S. Chaiyarat, "Preparation and characterization of low cost silica powder from sweet corn cobs," J Mater Environ Sci, vol. 7(7), pp. 2369-2374, 2016.
[36]. E. A. Okoronkwo, P. E. Imoisili and S.O.O. Olusunle, "Extraction and characterization of amorphous silica from corn cob ash by sol gel method," IISTE: Chemistry and Materials Research, vol. 3, pp. 68, 2013.
[37]. P. S. Utama, R. Yamsaengsung and C. Sangwichien, "Production and characterization of precipitated silica from palm oil mill fly ash using

CO2 impregnation and mechanical fragmentation," Brazillian Journal of Chemical Engineering, vol. 36, pp. 523-530, 2019.

[38]. M. Saleem et al., "Synthesis of precipitated silica from corn cob by using organic acids," Sci. Int. (Lahore), vol. 27(1), pp. 265-269, 2014.

[39]. A. Dauda, "Exploring the Potential of Alternative Pozzolona Cement for the Northern Savannah Ecological Zone in Ghana," American Journal of Civil Engineering, vol. 4(3), pp. 74-79, 2016.

[40]. A. Price, R. Yeargin, E. Fini and T. Abu-Lebdeh, "Investigating effects of introduction of corncob ash into Portland cements concrete: mechanical and thermal properties," American Journal of Engineering and Applied Sciences, vol. 7 (1), pp. 137-148, 2014.

[41]. R. Snellings, G. Mertens, J. Elsen, "Supplementary cementitious materials," Reviews in Mineralogy and Geochemistry, vol. 74, pp. 211–278, 2012.

[42]. American Society for Testing and Materials Standards ASTM, "AASHTO C618 Standard Specification for Fly Ash and Raw or Calcium Natural Pozzolanas for Use as a Mineral Admixture in Portland Cement Concrete, West Conshohocken, Pennsylvania, USA," vol. 04, 1992.

[43]. T. Chappex and K. Scrivener, "Alkali fixation of C-S-H in blended cement pastes and its relation to alkali silica reaction," Cement and Concrete Research, vol. 42, pp. 1049–1054, 2012.

[44]. C. Cherian and D. Arnepalli, "A Critical Appraisal of the Role of Clay Mineralogy in Lime Stabilization," International Journal of Geosynthetics and Ground Engineering vol. 1(1), pp. 1-20, 2015.

[45]. Investopedia, 2019. Available: https://www.investopedia.com/ articles /markets-economy/090316/6-countries-produce-most-corn.asp [Accessed Sep. 28, 2019].

[46]. N.M. Anosike, "Parameters for Good Site Concrete Production Management Practice in Nigeria," Ph.D dissertation, Dept. Civil. Eng., Covenant Univ., Otta, OG, 2011.

[47]. British Standards Institution, "BS EN 206 – 1: Concrete Specification, Performance, Production and Conformity" British Standard Institution, London," 2000.

[48]. British Standards Institution, "BS EN 12350 – 1, 2 & 3: Testing Fresh Concrete: Sampling; Testing Fresh Concrete: Slump Test; Testing Fresh Concrete: Vebe Test" British Standard Institution, London," 2009.

[49]. British Standards Institution, "BS EN 12390 - 1, 2 & 3: Testing Hardened Concrete shape, dimensions and other requirements for specifications and Moulds; Testing Hardened Concrete: Making and Curing Specimens for Strength Tests; Testing Hardened Concrete: Compressive Strength of Test Specimens" British Standard Institution, London," 2000.

[50]. American Society for Testing and Materials Standards, "ASTM C470 Standard Specification for Molds for Forming Concrete Test Cylinders Vertically, West Conshohocken, Pennsylvania, USA," vol. 04, 1994.

[51]. American Society for Testing and Materials Standards, "ASTM C31 Standard Practice for Making and Curing CONCRETE Test Specimens in the Field, West Conshohocken, Pennsylvania, USA," vol. 04, 2019.

[52]. The constructor, 2019. Available: https://theconstructor.org/concrete /chemical-attacks-types-concrete-structures/7237/ [Accessed Sep. 28, 2019].

[53]. https://www.cement.org/docs/default-source/fc_concrete_technology /durability/is536-types-and-causes-of-concrete-deterioration.pdf? sfvrsn=4 [Accessed Sep. 28, 2019].

[54]. British Standards Institution, "BS 4550: Methods of testing cement. Physical tests, British Standard Institution, London," 1978.

[55]. British Standards Institution, "BS EN 197-1: Composition, specifications and conformity criteria for common cements," 2000.

[56]. American Society for Testing and Materials Standards ASTM, "AASHTO T128: Standard method of test for fineness of hydraulic cement, West Conshohocken, Pennsylvania, USA," Vol. 04, 1992.

[57]. British Standards Institution, "BS 812-105.1: Methods for determination of particle shape" British Standard Institution, London," 1989.

[58]. British Standards Institution, "BS 812-103.1: Methods for determination of particle size distribution British Standard Institution, London," 1985.

[59]. British Standards Institution, "BS 812-103.2: Method for determination of particle size distribution British Standard Institution, London," 1989.

[60]. British Standards Institution, "BS EN 196-1: Methods of testing cement, British Standard Institution, London," 1995.

[61]. British Standards Institution, "BS 12: Specification for ordinary and rapid - hardening Portland cement, British Standard Institution, London," 1978.

[62]. British Standards Institution, "BS 1881, Part 102: Methods of Determination of Slump, London," 1983.

[63]. British Standards Institution, "BS 197 part 1: Composition, specifications and conformity criteria for common cements," 1985.

[64]. British Standards Institution, "BS 4027: Specification for sulphate-resisting Portland cement, British Standards Institution," 1991.

[65]. British Standards Institution, "BS 8500 - 1 : 2015: Concrete – Complementary British Standard to BS EN 206. Part 1: Method of specifying and guidance for the specifier. British Standards Institution (BSI), London, UK," 2015.

[66]. British Standards Institution, "BS 8500 1:2015: Concrete Complementary British Standard to BS EN 206. Part 1: Method of specifying and guidance for the specifier. British Standards Institution (BSI), London, UK," 2015.

[67]. British Standards Institution, "BS EN 1992 1 1: 2004: Eurocode 2: Design of Concrete Structures, Part 1 1: General Rules and Rules for Buildings. British Standards Institution (BSI), London, UK," 2004.

[68]. A.S. Alkali, "Optimization of Activated Carbon Preparation from Corncob Wastewater Treatment," MSc dissertation, Dept. Chem. Eng., Ahmadu Bello Univ., Zaria, KD, 2016.

[69]. M. O. Mulwa., T. O. J. Karanja, and M. J. Wachira, "Effect of sulphate ions in mixing water on cement mortar performance," IOSR Journal of Applied Chemistry (IOSR-JAC), vol. 9, pp. 11-15, 2016.