Journal of Materials & Manufacturing Technology

www.jmmt.reapress.com

J. Mater. Manuf. Technol. Vol. 1, No. 1 (2024) 1–8.

Paper Type: Original Article

Durability Characteristics of Corn-Cob Ash (CCA) Blended Cement Concrete

Ijwo Joel Ega[1,*], Olorunmeye Fredrick Job[1], Ikechukwu Solomon Anowai[1], Audu Isa Ibrahim Dakas[1]

[1] Department of Building Technology, Federal College of Education (Technical) Asaba, Delta State, Nigeria; egasaves@gmail.com, jobof1234@gmail.com, anowaiis@gmail.com, dakasaii@gamil.com.

Citation:

Received: 20 February 2024 *Revised: 11 March 2024* *Accepted:16 June 2024*	Ega, I. J., Job, F. O., Anowai, I. S. & Dakas, A. I. I. (2024). Durability characteristics of corn-cob ash (CCA) blended cement concrete. *Journal of Materials & Manufacturing Technology, 1* (1), 1-8.

Abstract

The durability of reinforced concrete is greatly hampered by the vulnerability of reinforcing steel to corrosion by water ingress, especially in an exposed environment. Water is the basic medium through which hazardous chemicals get into the concrete and then reinforcement. This study determines the durability characteristics of Corn-Cob Ash (CCA) blended cement concrete in water transport. Both review and experimental techniques were adopted as the research methodology. Materials tests and methods were prepared following ASTM, C 494. concrete mix was designed to obtain a compressive strength of 25N/mm² and 30N/mm² at 28 days with water-to-binder (cement/CCA) ratios of 0.45 and 0.50 respectively. Four different percentage replacements of Ordinary Portland Cement (OPC) (0%, 10%, 20%, and 30%) with CCA by weight of cement were adopted. The specimens were cured for 90 days while testing for the characteristics. The results show that CCA is a class N calcined natural pozzolan that attains its optimum characteristics strength between 56 and 90 days. Water transport, porosity/water absorption and sorptivity of the concretes were lower at 10% cement replacement than the corresponding control mix; thus, the durability of the concrete would be greater than one without CCA when combined with steel. Therefore, a designed strength of 30N/mm² containing 10% CCA-cement replacement in concrete is recommended for reinforced concrete construction prone to water ingress.

Keywords: CCA blended cement concrete, Durability, Porosity, Sorptivity, Water absorption.

1 | Introduction

The durability of a material can be described as the capacity to withstand any agent of deterioration. Describes the durability of a material as the ability to continue performing its specified function over a long period under normal use environments. It is also viewed as the capacity of a material to resist abrasion, chemical attack, weathering action, or any other degradation process American Concrete Institute. Though concrete is

Corresponding Author: egasaves@gmail.com

expected to withstand any condition to retain its serviceability and original properties, the durability of concrete would depend on its material constituents, quality of construction, and the service environment. Several researchers have measured durability, many of which were taken as the effect of chemicals on the constituents and their strength [1]. Thus, the test methods adopted were mainly immersion in diluted acids, which does not measure the durability characteristics of reinforced concrete. The durability of reinforced concrete, according to [2], simply depends on the water absorption resistance property.

Several parameters, including agents of deterioration, are usually measured to check for durability [3–5]. These include strength, chemical resistance, porosity water absorption, permeability, and sorptivity. The strength of a material is its ability to resist stresses caused by external forces, such as tension, compression, bending, torsion, and impact, without failure or fracture [6]. In this case, concrete compressive and flexural strengths are normally tested by subjecting it to loading to ascertain its load-carrying capacities.

According to [6], strength and durability are two separate characteristics that neither guarantee the other. This is because characteristic strength tests at normal conditions without subjecting concrete to any condition seem not to have any adequate measure of durability. The reason is that the bulk concrete that becomes the source of strength is, to some extent, shielded by the peripheral layer that controls durability. Concrete deterioration is amplified by ingesting destructive chemicals into concrete, followed by the reactions in the internal structure [7]. These chemical substances react with concrete constituents to weaken their strength, separating the bonds between the paste and other concrete constituents and the bond between the constituent materials themselves. This knowledge has always led to testing for durability by subjecting the concrete to immersion in diluted acid or other chemicals to measure the chemical resistance [1].

Concrete porosity, on the other hand, is a quality characteristic that depicts the amount of pores in concrete, and it has been widely used to forecast its characteristics. It is determined either by water soaking or by vacuum saturation. In this context, porosity is the quantity of water in the pore space, while the term -water absorption suggests a capillary suction measurement [2]. Porosity helps in studying a material's pore structure, which is important in determining the transport properties and, therefore, the durability characteristics [8].

Concrete durability is closely associated with the degree to which water permeates into it. The permeability measurements of concrete help check the durability of a material. It is viewed as the water flow rate through a saturated concrete under an applied pressure gradient. Permeability shows the concrete capability to convey water more accurately with a method that controls the application and movement of gaseous matter and water into cementitious material [7]. Permeability is measured in the laboratory as the passage of water through a saturated porous medium under pressure, but that is not obtainable. It is an inherent property of a material defined by a well-understood physical theory; however, theoretical high-pressure test conditions are not the same as those experienced in actual concrete structures [9]. According to Lee, this is because the permeability of modern high-performance concretes is so low that it cannot be accurately measured.

Sorptivity is the capacity of a medium to absorb liquid by capillarity. The material characteristic absorbs water and transmits it through a hardened, unsaturated medium via capillary suction. Sorptivity depends on a liquid's density, viscosity, surface tension, and the pore network (capillaries and tortuosity, radius) of a material [10]. The fluid and the quality of concrete determine the rate of liquid suction through capillary pore transport mechanisms. According to [9], Sorptivity is a durability parameter that is both simple to test and sensitive to concrete quality. It is strongly influenced by factors such as compaction and aggregate distribution, in addition, to mix composition and curing. Sorptivity as a value defining the speed of water penetration into concrete is the parameter that seems to be a good predictor of the permanence of concrete constructions as well as their resistance to corrosive factors influence [11]. The assessment of sorptivity is an unassuming index test for characterizing concrete durability [7]. it is a simple factor to consider in determining the durability of concrete and is gradually being used to measure the concrete resistance to aggressive chemicals [12].

The test method is comparable to a recognized deterioration process in real time. Sorption occurs when water is absorbed through the concrete interior by capillary forces. Concrete has better durability potential if the water sorptivity index is low [13]. Sorptivity provides an engineering measure of microstructure and properties important for durability. Sorptivity values vary from approximately 5 mm/√h for well-cured Grade 30-50 concretes to 15 – 20 mm/√h for poorly cured Grade 20 concretes [8]. Nicolas and Deventer [8] assert that lower sorptivity delivers a higher resistance of concrete towards water absorption, and a high sorptivity coefficient indicates the existence of a highly connected porous structure or low tortuosity of the pore network. The advantages of using the sorptivity test as a measure of durability, among others, according to Balakrishna et al. [7], are that:

I. It uses a mechanism relevant to actual deterioration processes in field concrete.

II. It reflects the overall concrete's pore network interconnectivity. On the other hand, the absorption test is more sensitive to total pore volume, a property more critical to strength than durability.

III. It has a well-developed mathematical framework for capillary flow in unsaturated materials, which unites both sorptivity and permeability and makes the material water content dependency explicit.

Several studies on the strength of Corn Cob Ash (CCA) blended cement have been reported to have impressive strengths suitable for structural works [4]. However, the durability characteristic of CCA blended concrete is not widely studied in the area of water transport to ascertain durability when used in reinforced concrete. Though reinforced concrete is considered a durable construction material, it is expected to be maintenance-free throughout its service period, which has never been the case. Saha and Sarker [2] observe that steel corrosion is reinforced concrete's most common durability problem. This is because the presence of water and its role in the reactions in concrete has always been the source of corrosion; thus, the durability of reinforced concrete is related to its water-tightness [2]. The durability of reinforced concrete, according to Kubissa and Jaskulski [11], is determined by the resistance to water penetration.

Thus, using strength and chemical resistance as durability parameters for concrete may only measure the durability of plain concrete but not reinforced concrete; this is because water into reinforced concrete could easily affect the reinforcing steel and other chemicals within the concrete. The rate of water absorption in concrete is normally attributed to its permeability or water-tightness, which is dependent on the perviousness of the concrete structure, i.e., cement paste, aggregates, and interfacial transition zone.

According to [14], Calcium leaching is responsible for increased concrete porosity and increased permeability, which allows water and other aggressive elements to enter the concrete, leading to carbonation and corrosion problems. Blending OPC cement with CCA in concrete is expected to increase durability by decreasing calcium leaching, which increases porosity since pores in a structure are a major factor in fluid transport.

Some properties of CCA blended concrete have already been reported by other scholars [15], [16], these properties include the classification of CCA as a class N pozzolana, improvement in compressive strength and improved resistance to chemicals in an aggressive environment. However, the water transport of CCA blended cement concrete has yet to be extensively studied. This study is thus designed to review scholarly articles related to the theme and experimentally measure the porosity, water absorption, and sorptivity as water transport parameters in CCA blended cement concrete for durability characteristics.

2|Methods

The current study applied both review and experimental research methods. The review extensively appraised scholarly articles related to the theme of this study and presented them in a tabular form. The experimental study was conducted to estimate water transport in CCA blended cement concrete. The water transport was measured in terms of water absorption, porosity, and sorptivity, and it is used as an index test for the durability performance of CCA blended cement concretes.

The materials for the experimental study were Ordinary Portland Cement (OPC), CCA powder obtained by the open burning process, portable water, and coarse and fine aggregates. Materials used in this study were tested for various properties needed for the mix design following the ASTM C 494, 1992. The cement used in the entire experiment was grade 53 OPC Dangote cement.

The highest coarse aggregate was 15mm, and river sand was used as fine aggregate. The concrete mix was prepared to have a design for $25N/mm^2$ and $30N/mm^2$ compressive strength at 28 days with water-to-binder (cement/CCA) ratios of 0.45 and 0.50, respectively. Four different percentage replacements of OPC (0%, 10%, 20%, and 30%) of CCA by weight of cement were adopted. Three samples were cast for each percentage replacement for the tests.

The testing of specimens was again carried out in accordance with ASTM C 494. Concrete specimens size $100\ mm^2$ x 50mm in height cast in molds were unmolded after 24 hours and then cured by soaking in water for 90 days at ambient temperature. Excess water remaining on the surface was dried out with a dampened tissue before being weighed, as the wet weight (Wwet) contained the concrete weight and that of the water.

The specimens produced were then dried in an oven at a temperature of 110°C until the sample mass remained constant after being severely weighed. The resultant weight was only recorded as the concrete dry weight (Wdry). The porosity *P was* then calculated as the decrease in mass caused by immersion based on the percentage mass of the dry specimen. Porosity, equivalent to Water absorption in percentage, is

$WA = [(W_{wet} - W_{dry}) / W_{dry}] \times 100$, Where W_{wet} = weight of the wet specimen in grams.

W_{dry} = Weight of oven-dry specimen in grams.

Sorptivity was determined by evaluating the rate of capillary rise by absorption [10] of water into the specimen. A selected number of the $100mm^2$ x 50mm height specimens that have been oven dried at a temperature of 110 °C were placed in water such that the water level remains 5 mm to the specimens' base and the absorption from the outer surface is prevented by sealing it properly with non-absorbent tape. Before weighing each specimen, the surface water on the specimen was wiped off with a tissue.

The weighting process was completed in 30 seconds. The weight of water absorbed upward within 30 minutes was evaluated by weighing the specimen with a weighing capacity of up to 0.1mg. The water absorption rate (WAr) was thus obtained as presented in *Fig. 1*, and the total water absorption (per unit area of the flow through the surface) increases as the square root of elapsed time (t).

$I=S.t^{1/2}$

Therefore, Sorptivity $(S)=I/ t^{1/2}$,

Whereas

S= sorptivity measured in mm.

t= elapsed time measured in mint.

$I=\Delta w/Ad$.

Δw = different in weight = W_2-W_1, while,

W_1 = Weight of the oven-dry specimen measured in grams.

W_2 = Weight of exposed specimen after 30 minutes (capillary suction in grams).

A= Area of the surface of the specimen through which water is absorbed.

Results and discussion

The results of the current study are twofold, namely, the findings obtained from the literature and the result of the experimental study. Both are discussed below.

Appraisal of related literature

The deductions from previous studies are summarized as follows:

I. CCA is a class N calcined natural pozzolana, thus suitable for use in concrete production without detrimental effects [15], [16].

II. The strength of CCA cement blended concrete rises with curing age up to 10% replacement and declines as the percentage replacement of CCA increases [16], [17].

III. Maximum strengths of CCA cement blended concrete are not attained at 28 days like OPC concretes but can be attained between 56 to 90 days depending on the mix ratio [18], [19].

IV. CCA blended cement concrete can be used for concrete structures but must be appropriately designed and specified [19].

V. The strength of CCA blended cement concrete has been widely tested, and the optimum replacement value appears to be 10% by weight for strength [5], [15].

VI. Very few studies on the durability of CCA blended cement concrete have been limited to chemical resistance. In that case, increased resistance to chemical attack (HCl and H2SO4) has been observed in the CCA-blended cement concrete [1].

VII. Durability studies in terms of water transport or ingress of liquid, such as sorptivity and porosity/water absorption, were scarcely considered.

Consequently, the experimental investigation of this study focuses on the porosity/water absorption and sorptivity of CCA blended concrete as durability measures.

3.2|Findings from the Experimental Study

Porosity: data recorded in *Table 1* clearly show that adding CCA into concrete has some influence on the porosity characteristics. A reduction in porosity was noted at 10% CCA substitutions, but beyond the 10%, the porosity increased over and above the control mix. This can be due to the finer particle nature of CCA filling the remaining pores in the mix, in which only 10% substitution appears to be the optimum or saturating point.

It could also be considered to reduce calcium leaching, as Pacheco-Torgal and Labrincha [14] observed. Thus, its durability will be higher than that of OPC concrete made without CCA since porosity determines water transport and durability [8]. However, the increase in porosity in a higher percentage of CCA - 20% and 30% can be due to the oversaturation of CCA in the spaces between the constituent materials, which creates additional voids, thereby increasing the porosity. Therefore, higher percentages of CCA cement blends (above 10%) cannot guarantee durability.

Table 1. Porosity of CCA blended concrete at 90 days.

Designation	Concrete Grade	% of CCA	Dry Weight	Wet Weight	Porosity in %
C_{25}	25	0	1200	1228	2.33
		10	1121	1140	1.78
		20	1116	1146	2.69
		30	1106	1145	3.62
C_{30}	30	0	1208	1234	2.15
		10	1142	1164	1.75
		20	1121	1149	2.50
		30	1116	1150	3.05

Water absorption Rate: from *Fig. 1* and *Fig. 2*, the water absorption is observed to be faster at an early stage within the first 30 minutes for all cases. The water absorption is generally slower in grade 30 (C30) than in grade 25 (C25). This could be due to an increase in fines in grade 30 concrete. The 10% CCA replacement in both cases was observed to be lower than others, as presented in *Fig. 1* and *Fig. 2*. The 10% optimum is comparable to the study conducted by Adesanya and Raheem [1], which obtained an optimum value of 8% where less water absorption was observed. The variation in the optimum values could be due to the differences in the quality of constituents used in the two studies.

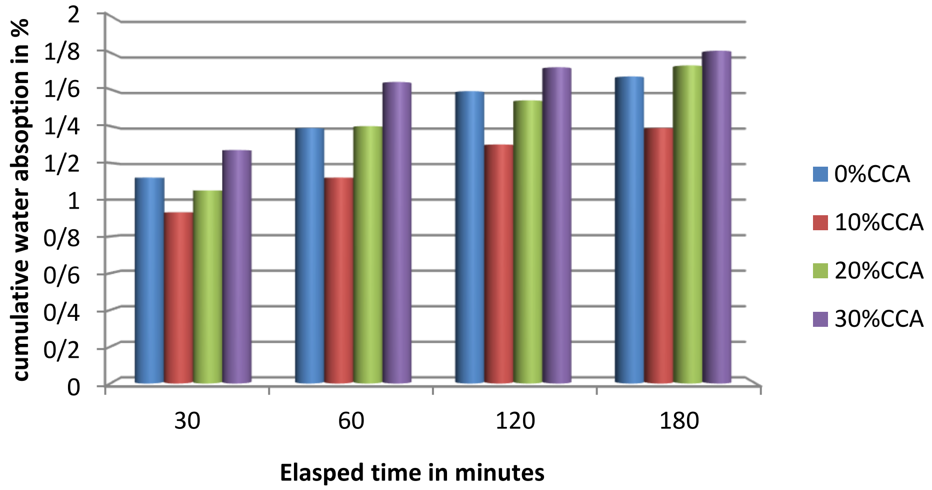

Fig. 1. Rate of water absorption of grade 25 (C25) CCA blended concrete.

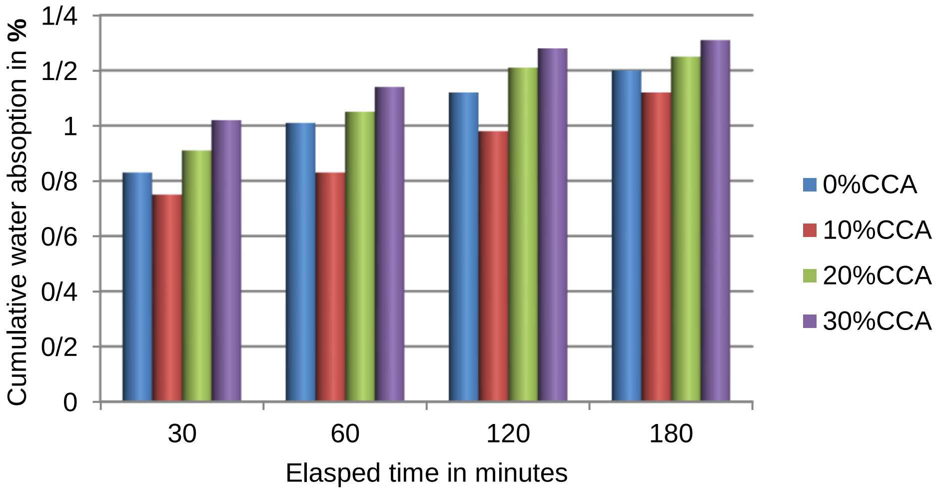

Fig. 2. Rate of water absorption of grade 30 CCA blended concrete.

Sorptivity: sorptivity is lowest at 10% replacement, as shown in *Table 2* and this is expected as the porosity is also lower in the mix. Generally, the sorptivity value is lower in grade 30 concrete (C30) than in grade 25 concrete (C25), which corresponds to the porosity ratio. The implication is that CCA blended cement concrete could be more impermeable and water-resistant than the control mix; hence, it could be considered more durable. The material will reduce water penetration and increase corrosion resistance, thereby increasing the concrete performance, as Nicolas and Deventer [8] observed. Consequently, it will perform better than concrete without CCA in an aggressive environment. However, if the quantity of CCA is increased beyond 10% in the mix, it could be detrimental to durability.

Table 2. Sorptivity of CCA blended cement concrete.

Designation	Concrete Grade	% of CCA	Dry Weight	Wet Weight	Sorptivity Value in 10^{-5} Mm/Min$^{0.5}$
C_{25}	25	0	1200	1201.8	3.29
		10	1121	1122.5	2.74
		20	1116	1118.5	4.57
		30	1105	1107.8	5.12
C_{30}	30	0	1208	1209.5	2.74
		10	1142	1143.3	2.38
		20	1121	1123.0	3.66
		30	1116	1118.5	4.57

4 | Conclusion

The durability characteristics of CCA blended cement concrete were reviewed to establish the significance of this study. The study identified several parameters used for testing durability characteristics, some of which do not adequately measure the durability of reinforced concrete. This is because the simplest durability problem of reinforced concrete is the ingress of liquid, which could easily corrode reinforcing steel; hence, this study experimentally examines water transport, which included porosity, water absorption, and sorptivity of CCA blended cement concrete. Consequently, the following deductions were built on the purposes of this study;

I. Durability and strength do not complement each other, and the laboratory permeability test for high pressure is not obtainable naturally in concrete. Again, chemical resistance (test) as a durability check is more relevant to plain concrete than reinforced concrete. The most suitable durability measurements related to reinforced concrete are porosity and sorptivity since reinforced steels are most vulnerable to corrosion, aggravated by the rate of liquid transport in the concrete.

II. There is a limit to the addition of CCA in concrete to achieve an optimum reduced porosity of 10%, beyond which porosity will increase. The reduction in porosity will help reduce the inflow and storage of water or hazardous liquid flowing into the concrete since pores are the pathway through which water and other liquids enter the concrete.

III. CCA blended cement concrete could be considered more durable than its equivalent concrete without CCA due to a reduction in sorptivity. It will exhibit lower water penetration with increased corrosion resistance, thereby increasing the reinforced concrete performance.

IV. The water absorption appears to be slower as the grade of concrete increases with CCA; this implies that a higher grade of concrete will be more durable if blended with CCA at 10% cement substitution. Consequently, high-grade CCA concrete will be more appropriate for reinforced concrete construction in aggressive environments.

Acknowledgments

The authors thank the Department of Building, University of Jos, Plateau State, and the Federal College of Education (Technical) Asaba, all in Nigeria, for providing laboratory Facilities and Technicians during this work.

Author contributions

The four authors listed all contributed to the success of this research in generating title, structure, data sourcing, analysis, interpretation, and editing.

Funding

This work is not linked to any funding.

Data availability

The data used in this study were sourced and are available with the authors.

Conflicts of Interest

No potential conflict of interest exists among the authors that could affect the work presented in the article.

Reference

[1] Adesanya, D. A., & Raheem, A. A. (2010). A study of the permeability and acid attack of corn cob ash blended cements. *Construction and building materials*, *24*(3), 403–409. https://www.sciencedirect.com/science/article/pii/S0950061809000518

[2] Yang, L., Gao, D., Zhang, Y., Tang, J., & Li, Y. (2019). Relationship between sorptivity and capillary coefficient for water absorption of cement-based materials: theory analysis and experiment. *Royal society open science*, *6*(6), 190112. https://royalsocietypublishing.org/doi/abs/10.1098/rsos.190112

[3] Desai, P. H. (2018). Experimental study on corn cob ash powder as partial replacement of cement in concrete. *International research journal of engineering and technology (irjet)*, *5*(6), 724–728. https://www.academia.edu/download/57075784/IRJET-V5I6139.pdf

[4] Kamau, J., & Ahmed, A. (2017). Suitability of maize cob ash as a partial cement replacement. *Juniper online journal material science*, *2*(5), 1–3.

[5] Anjaneyulu, K. (2017). Partial replacement of cement concrete by waste materials. *International journal of engineering development and research*, *5*(2), 1374–1383. https://rjwave.org/ijedr/viewpaperforall.php?paper=IJEDR1702215

[6] Subramanian, N. (2019). Building materials, testing and sustainability. *Oxford university press*, *386*, 1-13.

[7] Balakrishma, M. N., Mohamad, F., Evans, R., & Rahman, M. M. (2018). *Assessment of sorptivity coefficient in concrete cubes.*

[8] San Nicolas, R. V. R., Walkley, B., & van Deventer, J. S. J. (2017). 7 - Fly ash-based geopolymer chemistry and behavior. In *Coal combustion products (CCP'S)* (pp. 185–214). Woodhead Publishing. https://www.sciencedirect.com/science/article/pii/B9780081009451000071

[9] Lee, N. (2002). *Use of sorptivity as a guide to concrete durability performance*. https//www.concretenz.org.nz/resource/resmgr/docs/conf/2002/s2_paper

[10] Pitroda, J., Umrigar, D. F. S., Principal, B., & Anand, G. I. (2013). Evaluation of sorptivity and water absorption of concrete with partial replacement of cement by thermal industry waste (Fly Ash). *International journal of engineering and innovative technology (IJEIT)*, *2*(7).

[11] Kubissa, W., & Jaskulski, R. (2013). Measuring and time variability of the sorptivity of concrete. *Procedia engineering*, *57*, 634–641. https://www.sciencedirect.com/science/article/pii/S1877705813008138

[12] Uzoegbo, H. C. (2020). 12 - Dry-stack and compressed stabilized earth-block construction. In *Nonconventional and vernacular construction materials (second edition)* (pp. 305–350). Woodhead Publishing. https://www.sciencedirect.com/science/article/pii/B9780081027042000123

[13] Maroliya, M. K. (2012). Estimation of water sorptivity as durability index for ultra high strength reactive powder concrete. *International journal of engineering research and development*, *4*(3), 53–56.

[14] Pacheco-Torgal, F., & Labrincha, J. A. (2013). The future of construction materials research and the seventh UN millennium development goal: a few insights. *Construction and building materials*, *40*, 729–737. https://www.sciencedirect.com/science/article/pii/S0950061812008185

[15] Kamau, J., Ahmed, A., Hirst, P., & Kangwa, J. (2016). Suitability of corncob ash as a supplementary cementitious material. *International journal of materials science and engineering*, *4*(4), 215–228.

[16] Suwanmaneechot, P., Nochaiya, T., & Julphunthong, P. (2015). Improvement, characterization and use of waste corn cob ash in cement-based materials. *IOP conference series: materials science and engineering* (Vol. 103, p. 12023). IOP Publishing. https://iopscience.iop.org/article/10.1088/1757-899X/103/1/012023/meta

[17] Price, A., Yeargin, R., Fini, E., & Abu-Lebdeh, T. (2014). Investigating effects of introduction of corncob ash into portland cements concrete: Mechanical and thermal properties. *American journal of engineering and applied sciences* *7*(1), 133–144. https://www.researchgate.net/profile/Taher-Abu-

[18] Ettu, L. O., Anya, U. C., Awodiji, C. T. G., Njoku, K. O., & Chima, A. C. (2013). Strength of ternary blended cement Sandcrete containing corn cob ash and pawpaw leaf ash. *Engineering research and applications (IJERA) issn*, 2248–9622. https://www.researchgate.net/profile/Chioma-Awodiji-

[19] Olafusi, O. S., & Olutoge, F. A. (2012). Strength properties of corn cob ash concrete. *Journal of emerging trends in engineering and applied sciences*, *3*(2), 297–301. https://journals.co.za/doi/abs/10.10520/EJC131057