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# An evaluation of the effects of Corncob Ash on the Properties of Concrete

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## Abstract

*Cement is the most energy-intensive and expensive material in concrete production. However, energy efficient and cost-effective concrete could be achieved using Supplementary Cementitious Materials (SCMs), which require less heating and emit less $CO_2$. The research evaluated the effects of corncob ash (CCA) as a partial replacement of cement on the properties of concrete. A grade 20 N/mm$^2$ concrete was produced using the Department of Environment (DoE) method of concrete mix design which served as control and another concrete was produced by partially replacing the cement content in the concrete with 5, 10 and 15% corncob ash. The concrete properties were evaluated for workability at the fresh stage while the compressive strength was assessed at 3-, 7-, 14- and 28-days curing periods. The specimens were characterized using scanning electron microscopy (SEM-EDX) and Fourier Transform Infrared Spectroscopy (FTIR). Result shows decrease in slump value and increase in compressive strength with increase in the percentage of corncob ash. Samples with 5% corncob exhibited similar compressive strength (20.57 N/mm$^2$) compare to the control (20.87 N/mm$^2$) at 28 days of curing, as confirmed by SEM-EDX images and FTIR result. The addition of CCA leads to increase in water absorption. Therefore, corncob ash can be used to replace up to 15% cement in concrete production, and where higher compressive strength is required, 5 % replacement is recommended.*

**Keywords**: Concrete, Corncob ash, C-S-H, SEM-EDX, FTIR

## Introduction

Concrete is the most widely used construction materials and cement is the most energy-intensive and expensive material in concrete production. The manufacture of cement poses a sustainability threat as its production emits a large amount of carbon dioxide ($CO_2$) into the atmosphere coupled with the high consumption of natural resources (Bheel and Adesina, 2021). It is a known fact that production of cement consumes high energy and is responsible for about 5% of global $CO_2$ emission. The production of 1 ton of cement releases about 900 Kg $CO_2$ (Bakhtyar *et al*., 2017) . However, the use of supplementary cementitious materials (SCMs) as alternative to cement has been acknowledged by many researchers (Juenger *et al*., 2019; Rukzon and Chindaprasirt, 2012; Samad and Shah, 2017).

On the other hand, there exist several wastes from the agricultural industry (oil palm empty fruit bunch, rice husk, rice straw, sugarcane bagasse, wheat straw, corn cob, etc.) that can be incinerated, and the resulting ash used as a replacement of cement (He *et al*., 2020). Corn cob is one of such promising agricultural wastes that can be converted into corn cob ash (CCA) and use as cementitious material in concrete. Nigeria, being second's African largest maize producer after South Africa and the 14$^{th}$ largest producer globally produced about 11.6 million metric f maize in 2021 according to United States Department of Agriculture (Management and Security, 2010; Ranum *et al*., 2014). This high production of corn means that there will be a corresponding generation of an equal amount of corn cob. Therefore, the use of such waste material into concrete will help to manage the wastes effectively while creating future demand of binders for concrete production.

Moreover, available literatures have shown that using CCA as partial replacement of cement in concrete or mortar is a promising way to cutting down the amount of cement production which help to reduce energy and raw materials consumption in addition to cleaning the environment (Assefa, 2019; Desai, 2018). Corn Cob Ash was partially utilized as supplementary cementitious material (SCM) for cement and artificial fibers as micro reinforcement. This is with the view to find the effect of CCA on fresh, mechanical and microstructural properties of high-performance concrete through testing(Mohan and Chandrasekaran, 2022). Results showed that 15% of CCA as partial replacement of cement along with 0.4% artificial fibers gave better compressive, tensile, flexural strength as well as improved microstructure of the specimens**.** Gradinaru *et al*., (2019) investigated the effects of 5%, 10% and 15% volume replacement of cement with corn cob ash (CCA) on the concrete density, compressive strength, flexural and splitting tensile strengths. Results showed that CCA decreased the values of compressive and tensile strengths of the concrete, but it improved its density. It was concluded that 5% CCA is regarded as optimum percentage replacement.

In another vein, the effects of corn-cob ash (CCA) on the durability of self-compacting concrete (SCC) was evaluated by Ogork and Auwal, (2017). Outcome of the study revealed decrease in compressive strength of the SCC with increase in CCA content. It was concluded that CCA increased the water absorption of SCC and up to 15% can be used as partial replacement of cement. However, there is lack of intensive studies on the use of CCA as SCMs for concrete. Also, studies on the use of CCA have evaluated only compressive, tensile and flexural strengths while durability properties such as water absorption capacity and sorptivity were neglected in conventional concrete. Moreover, only few past studies assessed the microstructure of the concrete made with the CCA as partial replacement of cement. Therefore, there is the need to evaluate the effects of CCA on the properties of concrete.

## Materials and Methods

### Materials

The materials used in this experiment were cement, corn cob ash (CCA), fine aggregate, coarse aggregate and water in accordance to the relevant standards. The cement is blended cement of BUA brand (42.5 R). The Corncob was collected from local farmers in Samaru, Sabon Gari LGA of Kaduna State while the CCA was obtained by air-drying and burning the corn cob to ashes using open burning process at an average temperature of 700 $^0$C (this is to ensure proper burning) as shown in Figure 1. The ash was then ball milled using ball milling machine in the Department of chemical engineering, Ahmadu Bello University Zaria. The fine grain was then sieved using 75µm sieve size to produce finer ash. The CCA has not satisfied the requirement of ASTM C 618 as shown in Table 1, because the summation of $SiO_2$, $Al_2O_3$ and $Fe_2O_3$ is less 70%. However, the CCA satisfied the requirement of BS EN 197-1:200 of $SiO_2$ content of at least 25%. The variation in the chemical compositions could be attributed to the source of the corncobs and methods of burning used (Olafusi and Sadiku, 2018). However, the chemical composition of the CCA can be improved by burning the corncobs under controlled conditions (Ahmed and Kamau, 2017,). Other properties of the constituent materials of the concrete are shown in Table 2.

**(a)** Raw Corncob **(b)** Burning **(c)** CCA **(d)** Ball milling

**Figure 1**. Conversion of corn cob to corn cob ash

**Table 1**. Chemical composition of cementitious materials

| Oxides (%) | $K_2O$ | $SiO_2$ | CaO | $Al_2O_3$ | Cl | $Fe_2O_3$ | $P_2O_5$ | $SO_3$ | MgO | LOI |
|---|---|---|---|---|---|---|---|---|---|---|
| CCA | 32.59 | 26.89 | 10.37 | 5.64 | 5.29 | 5.28 | 4.97 | 3.93 | 2.55 | 3.78 |
| Cement | - | 10.47 | 68.76 | 1.09 | - | 3.82 | - | 2.02 | 6.13 | - |

**Table 2.** Properties of the constituent materials

| Materials | SG | Bulk density (kg/m$^3$) | Moisture content (%) | Absorption capacity (%) | AIV (%) | ACV (%) | SAI |
|---|---|---|---|---|---|---|---|
| Cement | 3.17 | 1324 | - | - | - | - | **82% ≥ 75%** |
| CCA | 2.51 | 1004 | - | - | - | - | |
| Fine aggregates | 2.61 | 1702 | 0.67 | 2.56 | - | - | |
| Coarse aggregates | 2.83 | 1542 | 0.27 | 0.22 | 26.67 | 21.67 | |

**Methods**

A grade 20 concrete was designed using Department of Environment (DoE) method of concrete mix design which served as control. Another concrete was produced by partially replacing the cement with corn cob ash (CCA) using 5%, 10% and 15%. At the fresh stage, the concretes were subjected to workability test. At the hardened stage, the specimens were assessed for density and compressive strength at 3, 7, 14 and 28 days. Workability, density and compressive strength tests were carried out in accordance with BS 1881: Part 102: (1983), BS 12390-7: 2019 and BS 1881: part 116, (1983) respectively.

**Durability tests**

At the end of 28 days curing, absorption test was conducted according to BS 1881-122 :( 1983). The test involves drying a specimen to a constant weight in an oven at 105$^0$C for 72 hours. The sample was allowed to cool in the oven, weighed and the mass recorded ($W_1$). Each sample was then immersed in water for 30 minutes. Thereafter, the specimens were removed from the water and dried with a cloth as rapidly as possible until all free water was removed from the surface and re-weighed again ($W_2$). The increase in weight as a percentage of the original weight is expressed as its absorption as shown below.

$$\text{Water Absorption (\%)} = \frac{w_2 - w_1}{w_1} \times 100 \quad (1)$$

Where, $W_1$ is the oven dry weight of cubes in grams and $W_2$ is the wet weight of cubes in grams.

Sorptivity test was performed in accordance with ASTM C1585-04. The purpose is to determine the rate of absorption of water by unsaturated concrete (capillary rate of absorption of water). Sorptivity is a function of the increased mass of a specimen resulting from absorption of water, relative to the time that one surface is exposed to water. The specimens of the concrete were removed from the curing tank and allowed to dry. They were then put inside an oven and dried at temperature of 50±2$^o$C for 72 hours. At the end, Abro 2000 RTV silicone sealant was applied on the sides of the specimens in order to prevent water ingress through the sides of the specimens. The specimens were then weighted and the masses recorded. Specimens were subjected to Sorptivity test at 1, 5, 10, 20, 30, 60 minutes, 1, 2, 3, 4, 5 and 6 hours and the change in masses were recorded after each testing period.

## Microstructure analysis

Microstructure analysis was carried out using Scanning Electron Microscope with energy dispersive technique (SEM-EDX). This is a type of microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample. Fourier transform infrared spectroscopy (FTIR) was also used to understand the structure of individual molecules and the composition of molecular mixtures. It uses a modulated, mid-infrared energy to interrogate a sample. The analysis was only conducted on control and 5 % specimen.

## Results and discussions

### Workability

Figure 2 shows the slump values of the 0%, 5%, 10% and 15% concrete samples made with corn cob ash (CCA) as partial replacement of cement in concrete. Decrease in slump values can be observed with increase in partial replacement (from 5% to 15%) of cement with CCA. The control specimen has 37mm slump values while 5% and 15% CCA replacement have 36 and 17mm respectively. The 5% CCA has similar slump value (306mm) to the control while 15% CCA has the lowest slump value (46% lower than the control). This shows that the addition of CCA decreases the slump values (Assefa, 2019) requiring more water to make the mixes more workable as a result of increase in silica amount in the concrete (Bheel and Adesina, 2021).

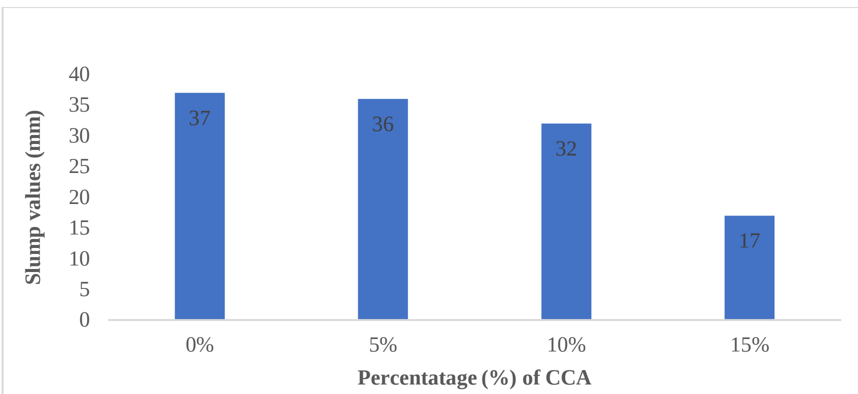



**Figure 2:** Effect of CCA content on Slump of concrete

## Hardened Properties

### Concrete Density

Figure 3 shows the density of the concrete specimens at 28 days. After 28 days of curing, before the samples were checked for compressive strength, their mass was measured. A decrease in density can be observed with increase in percentage replacement of cement with CCA. The density ranges from 2385 to 2450 $kg/m^3$ with 0 % replacement having the highest density while 15 % having the lowest density. The decrease in the density of the CCA replaced specimens was as a result of lower bulk density of the CCA as shown in Table 2. Similar finding was reported by (Karim *et al*., 2024). This shows that 15% CCA specimens can be used in making light weight concrete (Assefa, 2019).

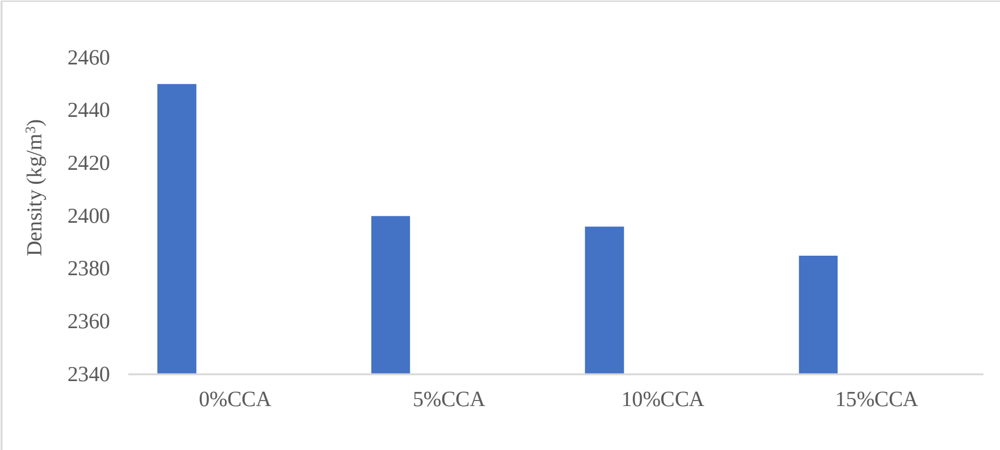



**Figure 3:** Effect of CCA content on the Concrete Density

## Compressive Strength

Figure 4 shows the compressive strength results of cement-CCA concrete specimens at 3-, 7-, 14- and 28-day curing age. It can be seen from Figure 4 that the compressive strength of all mixtures increased with age irrespective of the binder composition. At the early age (3 days), the compressive strength ranged from 11.49 N/mm$^2$ to 13.45 N/mm$^2$. The results showed that the cubes containing 15% CCA had the highest compressive strength in the first three days while 0%, 5%, 10% and 15% replacement all satisfied the minimum required compressive strength of 40% and 65% of the designed strength (20 N/mm$^2$) in the first three and seven days respectively (IS 456-2000 for conventional concrete). After 14 days of curing, the compressive strength ranged from 14.59 N/mm$^2$ to 18.20 N/mm$^2$. The 5% replacement had the highest compressive strength of 18.20 N/mm$^2$ representing 91% compressive strength as against the 90% required by the IS 456-2000 after 14 days of curing while other specimens (0, 10, and 15 %) were having 72.95, 79.8 and 75.20 % respectively. At 28 days, the control samples and 5 % replacement had compressive strengths of 20.87 N/mm$^2$ and 20.57 N/mm$^2$ (104% and 103 % of the designed strength) respectively (Gradinaru *et al.*, 2019). The 10% and 15% replacements had 17.44 and 16.46 N/mm$^2$ respectively. One of the reasons for the low compressive strength in 10% and 15% was that some supplementary cementitious materials only act as fillers at the early age, then react at a latter age to form further Calcium Silicate Hydrate (Chakrapani *et al.*, 2019; Kanamarlapudi *et al.*, 2020). In the latter ages, SCMs-replaced concrete could develop strengths that are higher than those of 100% cement(Hannesson *et al.*, 2012).

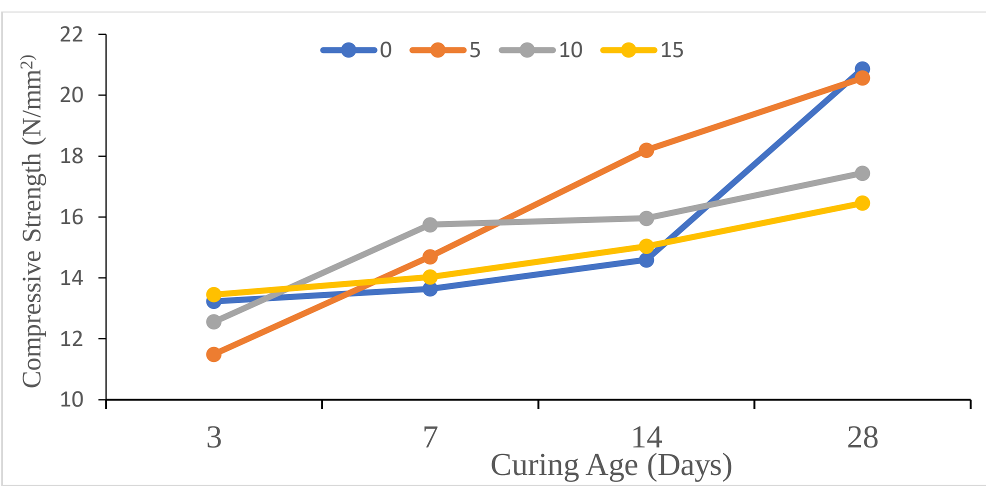



**Figure 4:** Effect of CCA content on the Compressive strength of the concrete

## Durability Properties

### Water absorption

Figure 5 shows the water absorption capacity (%) of the concrete specimens at 28 days. The water absorption ranged from 2.79% to 4.30% with the control specimen having the lowest and 15% having the highest water absorption capacity. It shows that the water absorption capacity increases with increase in percentage of CCA as reported by Ahmed and Kamau, (2017).

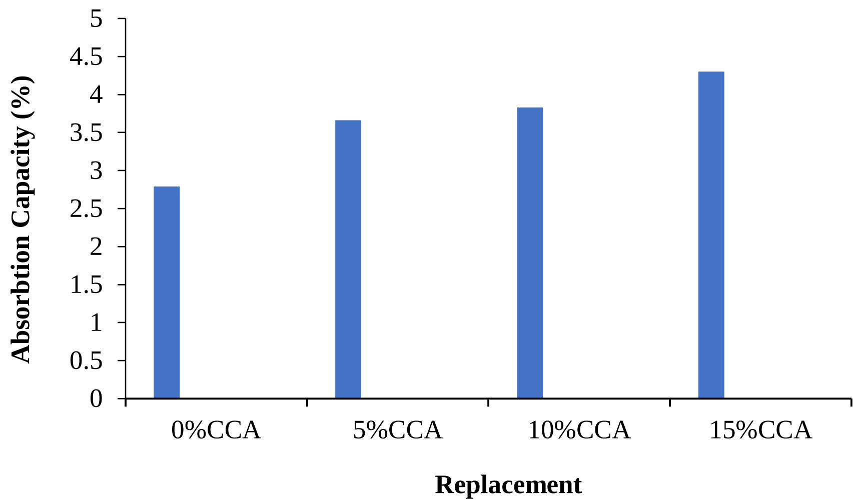



**Figure 5:** Effect of CCA on the Water absorption chart

### Sorptivity

Figure 6 shows the result of sorptivity of the concrete specimens (0, 5, 10 and 15 %) at 28 days curing. It can be seen that there is increase in the rate of absorption (sorptivity) with increase in percentage replacement of CCA. The result showed that specimens replaced with 15% CCA had highest sorptivity of 0.5 mm/√s and the control specimen had the lowest sorptivity of 0.15 mm/√s. This means that CCA has the tendency to increase the sorptivity of a concrete when used as partial replacement of cement. This finding is in agreement with what was reported by (Kifile *et al*., 2022)

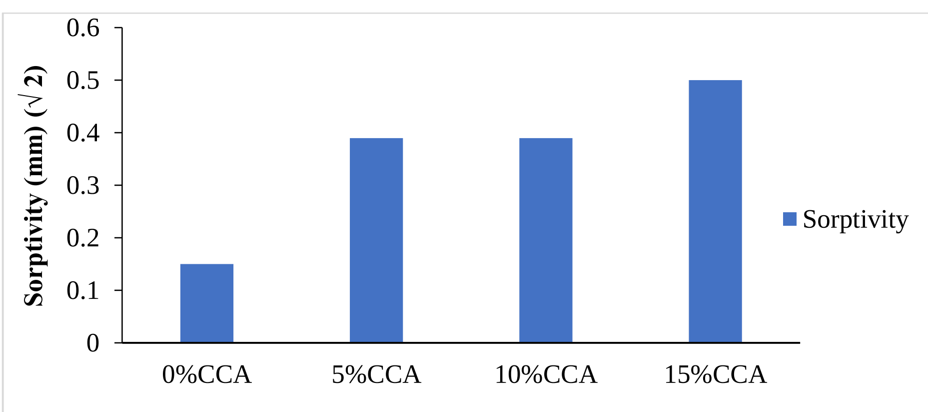
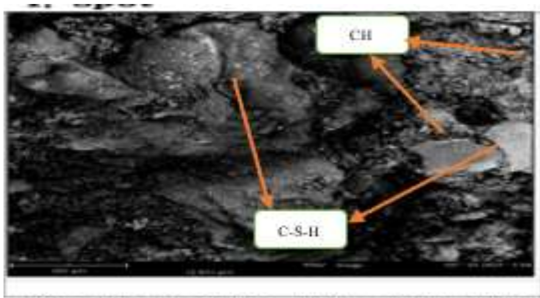



**Figure 6:** Sorptivity

## Microstructure Properties

### SEM with energy-dispersive x-ray spectroscopy (EDX)

Figure 7 (a &b) shows the SEM-EDX images for the control and 5 % CCA specimen at 28 days. Chemical composition of hydration products was investigated by the SEM-EDX. Some spots were located in the microstructure of each concrete specimen to quantify Ca/Si ratio of C-S-H. It can be observed from Figure 6b that the SEM-EDX spectrum of the 5 % CCA imparts more siliceous compound to mix after the pozzolanic reaction with higher Ca/Si ratio than that of control concrete in Figure 6a. This indicated that the consumption of calcium hydroxide in CCA concrete was due to the pozzolanic reaction that resulted in more C-SH gel formation with lower Ca/Si ratio than the control specimen (Amin *et al*., 2019; Shahbazpanahi *et al*., 2021).

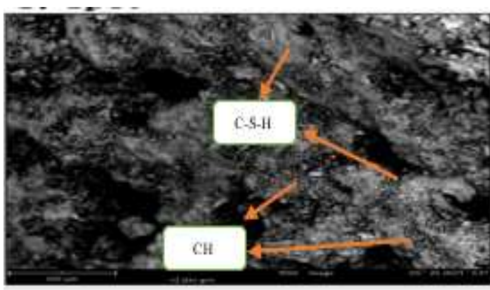



| Element Number | Element Symbol | Element Name | Atomic Conc. | Weight Conc. |
|---|---|---|---|---|
| 8 | O | Oxygen | 53.96 | 28.47 |
| 20 | Ca | Calcium | 14.75 | 19.50 |
| 6 | C | Carbon | 13.32 | 5.28 |
| 52 | Te | Tellurium | 7.73 | 32.53 |
| 14 | Si | Silicon | 7.46 | 6.91 |
| 35 | Br | Bromine | 2.78 | 7.31 |

FOV: 895 µm, Mode: 10kV – Image, Detector: BSD Full, Time: OCT 25 2021 12:34

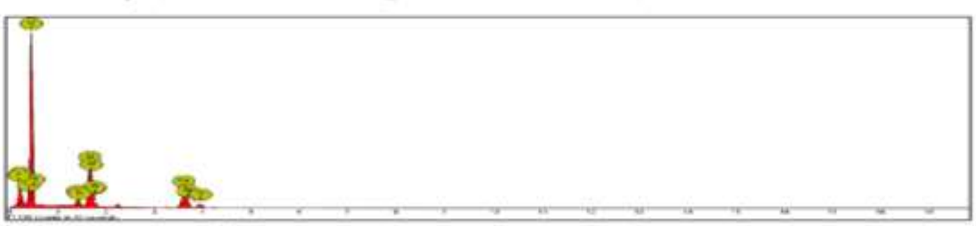
Disabled elements: B

**(a)** Control Specimen




| Element Number | Element Symbol | Element Name | Atomic Conc. | Weight Conc. |
|---|---|---|---|---|
| 8 | O | Oxygen | 62.63 | 36.47 |
| 6 | C | Carbon | 16.89 | 7.38 |
| 20 | Ca | Calcium | 7.03 | 10.25 |
| 14 | Si | Silicon | 5.97 | 6.10 |
| 52 | Te | Tellurium | 3.34 | 15.52 |
| 74 | W | Tungsten | 3.23 | 21.64 |
| 35 | Br | Bromine | 0.91 | 2.64 |

FOV: 895 µm, Mode: 10kV – Image, Detector: BSD Full, Time: OCT 25 2021 13:37



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**(b)** 5%CCA Specimen

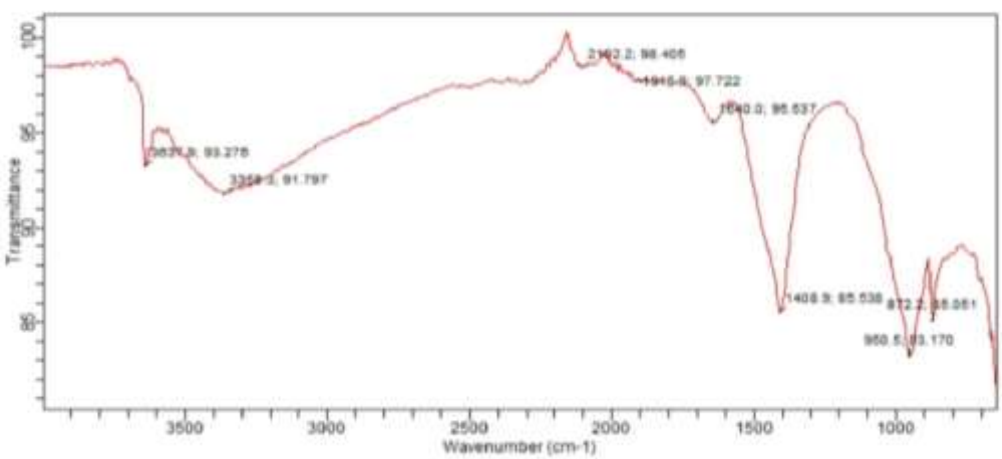
**Figure 7:** SEM with EDX of the concrete Specimens

## Fourier transform infrared spectroscopy (FTIR)

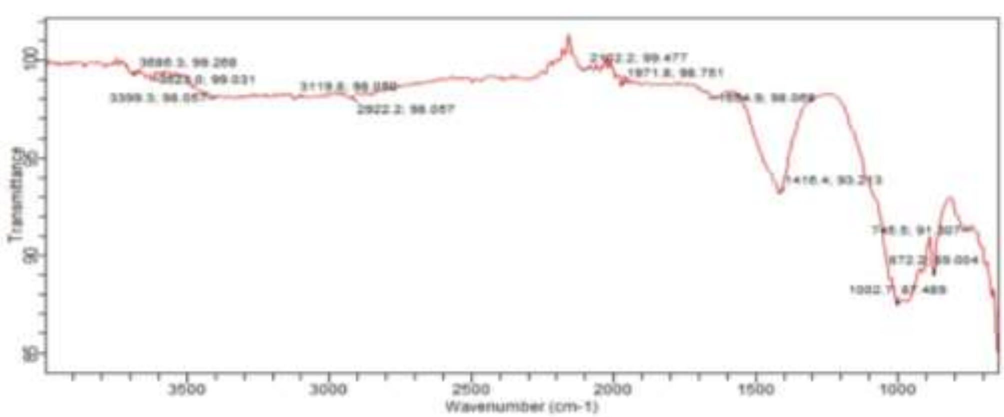
Table 3 shows the summarised FTIR results (shown in Figure 7a & 7b) of Control and CCA specimens (0% & 5%) at 28 days curing. The essence of the FTIR studies is to identify different interactions of $Ca(OH)_2$ with $SiO_2$. The peaks at 3642 $cm^{-1}$ to 3645 $cm^{-1}$ are due to O-H stretching vibrations related to $Ca(OH)_2$. The C-S-H of the CCA specimen exceeded that of the control specimen with wave numbers of 1003 and 951 $cm^{-1}$ (lower frequency corresponds to a lower degree of polymerization) for 5% and 0% respectively (Ellerbrock and Gerke, 2021; Mahene *et al*., 2020). This indicates the formation of polymerized calcium silicate hydrates (C-S-H) which is the most significant infrared spectra. The C-S-H transmittance of 83.170% and 87.49% was obtained for 0% specimen and 5% specimen respectively. The result of the FTIR is line with that of compressive strength and SEM-EDX.

**Table. 3:** Summary of FTIR results at 28 days

| Specimen | Product | Wave number ($cm^{-1}$) | Transmittance T (%) |
|---|---|---|---|
| | CSH gel | 951 | 83.170 |
| 0% | CH | 3638 | 93.275 |
| | $CaCO_3$ | 872/1640 | 85.051/95.537 |
| | CSH gel | 1003 | 87.49 |
| 5% | CH | 3686 | 99.268 |
| | $CaCO_3$ | 872/1416 | 89.004/93.213 |




**(a)** Control




**(b)** 5 % CCA

**Figure 8:** FTIR results of concrete specimens at 28 days

## Conclusions

Based on the outcomes of the research, the following conclusions are drawn:

i. CCA decreases the workability of concrete, i.e., an increase of the percentage of CCA material leads to decrease in workability
ii. The 5% replacement has a comparable compressive strength to the control.
iii. 5% CCA is the optimum % replacement and, up to 15% can be used in the production of concrete where low density concrete is desired.
iv. Water absorption capacity and sorptivity increases with increase in CCA % replacement
v. SEM-EDX and FTIR analyses showed evidence of pozzolanic reaction in the specimen with 5% CCA and also the presence of C-S-H gel resulted from the pozzolanic reaction.
vi. Moreover, the use of the CCA can lead to production of strong and sustainable concrete by reducing carbon emission as well as reducing the use of corncob as landfill.

## References

Ahmed, A., and Kamau, J. (2017). A review of the use of corncob ash as a supplementary cementitious material. *European Journal of Engineering and Technology Research*, *2*(8): 1–6. https://doi.org/10.24018/ejeng.2017.2.8.415

Amin, M. N., Hissan, S., Shahzada, K., Khan, K., and Bibi, T. (2019). Pozzolanic reactivity and the influence of rice husk ash on early-age autogenous shrinkage of concrete. *Frontiers in Materials*, *6*(July), 1–13. https://doi.org/10.3389/fmats.2019.00150

Assefa, S. (2019). Production of lightweight concrete using corncob ash as replacement of cement in concrete. *American Journal of Civil Engineering*, *7*(1): 17. https://doi.org/10.11648/j.ajce.20190701.13

Bakhtyar, B., Kacemi, T., and Nawaz, A. (2017). *A review on carbon emissions in Malaysian cement industry*. *7*(3): 282–286.

Bheel, N., and Adesina, A. (2021). Influence of binary blend of corn cob ash and glass powder as Partial Replacement of Cement in Concrete. *Silicon*, *13*(5): 1647–1654. https://doi.org/10.1007/s12633-020-00557-4

Chakrapani, E. T., Kashhyap, A. M. N., Raju, S. S., and Ramesh, K. V. (2019). *Influence of dosage of chemical and Mineral Admixtures on the Compressive Strengh of Concrete*. *6*, 20–23.

BS 1881: Part 102 (1983). Method for determination of slump, British standard institutions

BS 1881: Part116 (1983). Method for determination of compressive strength of concrete cubes, British standard institutions

BS EN 197: Part 1 (2000). Composition, specifications and conformity criteria for common cements, British standard institutions

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*.

Ellerbrock, R. H., and Gerke, H. H. (2021). *FTIR spectral band shifts explained by OM – cation interactions*. *1*, 1–10. https://doi.org/10.1002/jpln.202100056

Gradinaru, C. M., Barbuta, M., Babor, D., and Serbanoiu, A. A. (2019). Corn cob ash as sustainable puzzolanic material for an ecological concrete. *Bulletin of the Transilvania University of Brasov. Series I - Engineering Sciences*, *11*(60): 61–66.

Hannesson, G., Kuder, K., Shogren, R., and Lehman, D. (2012). The influence of high volume of fly ash and slag on the compressive strength of self-consolidating concrete. *30*, 161–168. https://doi.org/10.1016/j.conbuildmat.2011.11.046

He, J., Kawasaki, S., and Achal, V. (2020). The utilization of agricultural waste as agro-cement in concrete: A review. *Sustainability (Switzerland)*, *12*(17). https://doi.org/10.3390/SU12176971

Ibrahim, A. G., Mu'azu, U., Usman, J., Gambo, S., Ibrahim, M. M., and Sani, A. M. (2023). Statistical analysis of strength properties of reactive powder concrete produced from unrefined metekaolin and gear inner wire. *Nigerian Journal of Technology*, *41*(6): 940–948. https://doi.org/10.4314/njt.v41i6.3

Juenger, M. C. G., Snellings, R., and Bernal, S. A. (2019). Supplementary cementitious materials: New sources, characterization, and performance insights. *Cement and Concrete Research*, *122*(February 2019), 257–273. https://doi.org/10.1016/j.cemconres.2019.05.008

Kamau, J., and Kangwa, J. (2017). *Viability of using corn cob ash as a pozzolana in*. *December 2016*.

Kanamarlapudi, L., Bhanu, K., Durga, J., and Kumar, C. (2020). Different mineral admixtures in concrete : a review. *SN Applied Sciences*, *2*(4): 1–10. https://doi.org/10.1007/s42452-020-2533-6

Kang, F., and Li, J. (2020). Displacement Model for Concrete Dam Safety Monitoring via Gaussian Process Regression Considering Extreme Air Temperature. *Journal of Structural Engineering*, *146*(1): 1–16. https://doi.org/10.1061/(asce)st.1943-541x.0002467

Karim, A., Habib, A., Koteng, D. O., and Ambassah, N. (2024). *Effect of Pretreated Corn Cob Ash on the Mechanical and Durability Characteristics of High-Strength Concrete*. *11*(3), 125–138.

Kifile, D., Getu, N., Mesfin, A., Yifru, W., and Sewunet, A. (2022). Evaluation of Maize Cob Ash as Filler in Hot-Mix Asphalt Concrete Production Evaluation of Maize Cob Ash as Filler in Hot - Mix Asphalt Concrete Production. *International Journal of Pavement Research and Technology*, *January*. https://doi.org/10.1007/s42947-021-00150-x

Mahene, W. L., Gervas, C., Hilonga, A. H., and Machunda, R. L. (2020). *Synthesis and FTIR Characterization of Mg-Hydroxylapatite Derived from Dolostone with High Dolomite Mineral Content*. *46*(3): 661–672.

Management, A., and Security, F. (2010). *Www.Patnsukjournal.Net/Currentissue*. *6*(December), 15–25.

Mohan, S., and Chandrasekaran, P. (2022). *Effect of Artificial Fibers and Corn Cob Ash on Mechanical Behavior of High Performance Concrete*. *31*(4): 3713–3721. https://doi.org/10.15244/pjoes/146991

Ogork, E.-N. N., 100 Auwal, A. M. (2017). Ntui Ogork 1 , Abdulkarim Muhammad Auwal 2 CARD. *International Journal of Engineering and Emerging Scientific Discovery*, *2*(1): 2536–7269.

Olafusi, O. S., and Sadiku, E. R. (2018). *Characterization of corncob ash ( CCA ) as a pozzolanic material*. *9*(12): 1016–1024.

Ranum, P., Peña-Rosas, J. P., 9 Garcia-Casal, M. N. (2014). Global maize production, utilization, and consumption. *Annals of the New York Academy of Sciences*, *1312*(1): 105–112. https://doi.org/10.1111/nyas.12396

Rukzon, S., and Chindaprasirt, P. (2012). Utilization of bagasse ash in high-strength concrete. *Materials and Design*, *34*, 45–50. https://doi.org/10.1016/j.matdes.2011.07.045

Samad, S., and Shah, A. (2017). Role of binary cement including Supplementary Cementitious Material (SCM), in production of environmentally sustainable concrete: A critical review. *International Journal of Sustainable Built Environment*, *6*(2): 663–674. https://doi.org/10.1016/j.ijsbe.2017.07.003

Shahbazpanahi, S., Manie, S., Faraj, R. H., & Seraji, M. (2021). Feasibility study on the use of tagouk ash as pozzolanic material in concrete. *Clean Technologies and Environmental Policy*, *23*(4): 1283–1294. https://doi.org/10.1007/s10098-020-02021-8