GREENING TVET TOWARDS A MORE SUSTAINABLE CEMENT PRODUCTION USING MAIZE COB ASH

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Abstract

Technical and vocational education and training (TVET) institutions are being encouraged to align themselves to the growing calls for the execution of green strategies as desired by the United Nations in their collective agenda for accomplishing the targets of the sustainable development goals by 2030. Achieving the green strategies are dependent on quality education (SDG 4), sustainable and resilient infrastructure (SDG 9) and providing for all access to adequate, safe and affordable housing (SDG 11). All these are hinged on TVET because it is critical in addressing knowledge and skills challenges to achieving the targets of SDGs. Unsustainable human settlements environments coupled with environmental degradation as a results of nuisance caused by improper disposal of agricultural wastes necessitated re-orienting education and training at all levels on how to convert some of the agricultural wastes to sustainable materials that can be used to ease the ever increasing cost of providing affordable housing to the low income earners. This necessitated probing the potentials of Maize Cob Ash (MCA), an agricultural waste as sustainable substitute for cement by determining its pozzolanic capabilities through only calcinations but no laboratory work on the compressive strength of concrete cube made with MCA. Maize cobs were got from farms and sun dried properly before being calcined at temperatures ranging from 400^0C to 950^0C. The chemical composition of the resulting ash from its calcination determined through chemical analysis and X-ray diffraction (XRF). The results got from the chemical analysis, XRF and the control cement and comparing same with the standard stipulated by ASTM C618 for pozzolans showed that MCA calcined at the optimum calcining temperature of 800^0C has the highest summation of the three major oxides that determine how pozzolanic the waste is. The results are indication that MCA can suitably be used as cementitious materials.

***Keywords**: Housing, Cement, Maize Cob Ash, Pozzolanic, SDG, TVET.*

Introduction

The growing environmental concerns of cement production to greenhouse gases (Malek, R. I., & Roy, D. M. 1996, Uwasu, M. et al., 2014) has necessitated exploring options that are eco-friendly and that can perform satisfactorily as cement. The search has led to exploring agricultural wastes that have always been discriminately disposed as potential cementitious material that can be eco-friendly thereby giving impetus to the achievement of the sustainable development goals (SDGs) (Adegbesan *et al*., 2020). It is expedient to expatiate here that achievement of these goals such as SDG 9 (sustainable and resilient infrastructure sustainable and resilient infrastructure) and SDG 11 (access for all to adequate, safe and affordable housing) (UN, 2015) are all hinged on Technical and Vocational Education and Training (TVET) innovations. to solving economic and environmental challenges

Figure 1: Heap of Maize cob (www.agribusiness.co.zw)

This research seeks to integrate an effective innovative approach to harnessing of Maize cob, an agricultural waste as sustainable cement that can ameliorate the impact of the economic downturn on the low and middle income earners who now see housing as luxury and not within reach of the poor in line with TVET oriented solutions to economic and environmental challenges.

Many are yet to align with the possibilities of using agricultural wastes that are pozzolanic as substitute for cement in construction, so TVET is the lynch pin to the re-orientation of the growing population through the alignment of the curricula, teaching methodology and learning to be in line with global trends in response to desired innovations required to solve environmental quagmire that required not only the right skills and knowledge but also the attitude and choices for sustainability

Maize cob is one of the numerous agricultural wastes whose improper disposal will constitute nuisance to the environment and thereby affect the environmental health of the populace. Since building of an eco-friendly and sustainable environment is now a great concern, it is imperative to research into how this huge agricultural waste (maize cobs) can be reduced and be positively used for the betterment of the environment (Anowai,*et al*., 2020) especially at this time where the low and middle income earners need to believe in the renewed hope of President Bola Tinubu administration.

Research have shown that materials rich in amorphous silica can suitably replace cement either partially or completely. Moreso, that amorphous silica reacts with lime more readily compared to those of crystalline form thereby indicating that using such pozzolanic materials can possibly lead to increased strength of concrete in compression and flexure. This research will investigate the pozzolanic potential of Maize Cob Ash (MCA) and its optimum calcining temperature.

Pozzolans, according to the American society of testing materials (ASTM) are siliceous or aluminous materials having slight or no cementitious properties but if in powdery form with moisture, will react with calcium hydroxide [$Ca(OH)_2$] at ordinary temperature to form a compound with pozzolanic potentials. In furtherance to this, ASTM C 618 –78 specified that for any materials to be deemed pozzolanic and then used as a cementitious binder in concrete, the sum of its three oxides- silica, alumina and ferric oxides must be a minimum of 70%.

There have been numerous researches on the use of agricultural waste in the concrete industry (Kishore K and Gupta N. 2019, AlBiajawi, et al., 2022) affirmed the possibility of this type of waste in improving concrete quality. The pozzolanic potential of guava leaves ash and optimum calcining temperature was investigated by Adegbesan et al., (2020), their findings showed that at optimum calcining temperature of 600^0C, the sum of the oxides; SiO_2, Al_2SO_3, & Fe_2O_3 were greater than 70% as stipulated by ASTM C. Olonade (2015) investigated the pozzolanic potentials of Cassava Peel Ash CPA) by calcining the sun dried wastes at a temperature range of 500^0C to 1000^0C different time ranges between 30-90 minutes. His findings showed that at temperature of 700^0C, the CPA contained amorphous silica in abundance required for reactivity. Rice husk, another environmental waste potential as substitute for cement was investigated by Soyemi and Adegbesan (2020), the results of the flexural strength of the concrete beam made using rice husk ash (RHA) as partial replacement of cement, showed an increase in the flexural strength. They recommended 10% replacement as ideal for structural element and 20-30% for non-structural element. Olutoge *et al* (2012) considered the suitability of Palm kernel shell ash (PKSA), a by-product in palm oil mills as a partial replacement for cement and also its importance in the strength and durability of concrete. The results of the compressive strength of concrete cube made with PKSA was 22.8N/mm2 at 10% replacement. Concerns on durability of concrete made from cementitious agro-waste as partial replacement of cement was allayed by Hossain *et al*., (2016), he proposed that their use will apart from improving the durability properties of mortar and concrete, it will also ultimately reduce the cost of construction material coupled with minimization of their disposal challenges.

Pozzolans incorporated into ordinary Portland cement (OPC) minimizes concrete permeability by changing the pore structure with the concrete there reducing considerably the possibility of reinforcement corrosion (Adole et al., 1993).

Methodology

Maize cob/corn cob that have not been subjected to any form of heat were collected from a farm (N56^0 36^0E) located between Igbogila and Ibese in Yewa North area of Ogun State, Nigeria.

These were then sun dried for 7 days so as to reduce the moisture content to a bare minimum. The sun dried samples were then calcined at temperature range of 600^0C and 1000^0C. Both wet analysis and chemical analysis using X-ray Florescence machine (XRF) were used to determine the chemical composition of the Maize cob ash (MCA). The percentages of the following were determined

i. Silica (SiO_2)
ii. Ferric Oxide (Fe_2O_3)

iii. Combination of Ferric Oxide and Aluminium Oxide.
iv. Calcium Oxide (CaO)
v. Magnesium Oxide (MgO)
vi. Sulphur Trioxide (SO_3)
vii. Moisture Content and
viii. Loss On Ignition

Figure 2: XRF machine at Quality Control Laboratory of Lafarge cement factory at Ewekoro

Results and discussion

The results obtained from samples at varying temperature are summarized below.

Figure 3: Maize Cob Ash after calcination at optimum temperature at the laboratory

Table 1: Laboratory results of the Physical test at different temperatures

Temperature ^{0}C	400	500	600	700	800	950	Cement
Color	Dark Black	Ash	Dark Black	Ash	Dark black	Dark Black	Greyish
Concentration (M)	0.045	0.031	0.041	0.078	0.093	0.045	Not available

Salinity (ppm)	5021	5.29	5.35	5.41	5.49	5.60	2.04
Potential difference (V)	-310.4	-304.2	-298.2	-290	-285.9	-270.7	-279
Conductivity(S/m)	4.5	5.61	4.01	5.21	5.55	5.62	2.07
PH	9.0	8.6	6.7	7.9	8.9	7.5	11.24
**Fineness (μm)	1.90	1.90	1.90	1.90	1.90	1.90	2.82

**Values on this row were attained after grinding of the ash resulted from calcination

Table 2: Laboratory results of Chemical Analysis of MCA at different temperatures

Temperature Oxides	400^0C	500^0C	600^0C	700^0C	800^0C	950^0C
SiO_2	59.18	63.60	65.40	60.16	56.39	31.41
Al_2O_3	7.20	5.85	3.80	8.24	17.57	1.86
Fe_2O_3	1.09	2.95	5.80	7.81	9.07	1.20
MgO	2.0	2.11	2.30	1.27	0.98	2.12
CaO	3.20	3.50	2.97	3.04	3.47	1.70
N_2O	0.21	0.45	0.48	1.01	1.91	2.40
K_2O	7.36	8.452	8.39	6.34	1.98	20.50
SO_3^{2-}	1.20	1.14	1.10	0.84	0.55	0.17
P_2O_5	1.98	2.42	2.45	2.52	0	0
Mn_2O_3	0.03	0.06	0.06	0.07	0.08	0.18
TiO_2	0	0.60	0.64	0.70	0.70	0
LOI		8.55	6.49	5.69	4.21	17.30
$SiO_2+Al_2O_3+Fe_2O_3$	67.47	72.4	75	76.21	83.03	34.47

According to ASTM C618-13, three major oxides are use in classifying pozzolan to the three various classes of pozzolan which are Class N, Class F and Class C. The three major oxides are Silicon-Oxide, SiO_2; Aluminium-Oxide, Al_2O_3 and Ferric-Oxide, Fe_2O_3. It can be seen from the results in the table 2 above that the summation of the three major oxides increases from sample calcined at 400^0C temperature to 800^0C but at 950^0C, it has the lowest value of oxides. As seen in table 2, different values of oxides were obtained at different temperature, so, it is obvious that a sample can belong to different classes of pozzolan depending on the temperature at which the sample was calcined. Having seen the trend, it can be said that a sample can be a pozzolan at a range of temperature and also at the same time, the same sample might not be a pozzolan at a range of another temperature. At calcining temperature of 400^0C and 950^0C, Maize Cob Ash (MCA) can be classified as class C while at temperature range of 500^0C – 800^0C Maize Cob Ash (MCA) can be classified as Class F.

Table 3. Major compound in cement

Compound	Abbreviation designate	Term
Tricalcium silicate	C_3S	$3CaO.SiO_2$
Dicalcium silicate	C_3S	$2CaO.SiO_2$
Tricalcium aluminate	C_3A	$3CaO.Al_2O_3$
Tetracalciumalumino-ferrite	C_4AF	$4CaO.Al_2O_3.Fe_2O_3$

(theconstructor.org/concrete/compounds-cement-strength)

Where C = CaO, S = SiO_2, A = Al_2O_3 and F = Fe_2O_3

The equations 1-4 are what is known as Bogue's equation. The equations are best suited to calculating the approximate amount of the **C**$_3$S, **C**$_2$S,**C**$_3$A, and **C**$_4$AF in portland cement

$C_3S = 4.0710CaO - 7.6024SiO_2 – 1.4297 Fe2O3 + 6.7187Al_2O_3$………… (1)

$C_2S = 2.86024SiO_{2\,+\,1.0785} Fe2O3 + 5.0683 Al_2O_3 – 3.0710CaO$ ………… (2)

$C_2A = 2.6504Al_2O_3 – 1.6920Fe2O3$ …………. (3)

$C_4AF = 3.0432Fe_2O_3$ …………. (4)

$C_3S = 4.07CaO - 7.6024SiO_2 - 6.7187Al_2O_3$………… (5)
$C_2S = 2.8675SiO_2 - 0.7544C_3S$ ………… (6)
$C_2A = 2.6504Al_2O_3 - 0.7544C_3S$ …………. (7)
$C_4AF = 3.0432Fe_2O_3$ …………. (8)

The equations (5-8) above are Bogue's model for calculating the compound composition of cement substituted with the different agro-waste ash, because of the difficulty posed by the direct determination of main compound which are Alite (C_2S), Belite (C_3S), Aluminate (C_2A) and Ferrite (C_4AF). These equations are used to calculate the major compounds in the Maize cob ash and the summary is shown in table 4

Table 4: Major compound of MCA at varying calcining temperature using equations 5-8

Temp. Comp.	400^0C	500^0C	600^0C	700^0C	800^0C	950^0C	**Cement OPC**
C_3S	-486.67	-512.63	-518.76	-511.35	-545.43	-246.01	40
C_2S	536.79	569.10	578.84	573.26	573.09	275.64	30
C_3A	17.24	10.52	0.27	8.64	31.23	2.90	11
C_4AF	3.314	2.87	17.63	23.74	27.57	3.65	12
$C_3S + C_2S$	50.12	56.47	60.08	61.91	27.66	29.63	70
$C_3S + C_4AF$	67.36	13.39	17.90	32.38	58.80	6.55	23

Table 4 gives the range of values for the approximate proportions of the important minerals in cement clinker**.** C_3S is known to contribute to hardening of cement within the first 7 days while C_2S is for strength gain at later age after the 7 days and up to a year, the combination of the two i.e. $C_3S + C_2S$ gives a least value at 800^0C which is 40% less than the value of the ordinary Portland cement. This indicate that the strength gain of MCA will be slower at initial stage indicating that though it can replace cement, it cannot be used where concrete is needed to dry up as soon as possible such as in road pavement that required early opening for traffic. The $C_3S + C_4AF$ values at the same temperature gives a value that accounts for its distinct tint as filler cement and its prospect to gain strength that can make it to be of good use for hydraulic structures

Conclusion

After the rigorous and thorough analyses (Chemical and Physical) which was carried out in line with the international best practices of pozzolan on the sample Maize Cob Ash (MCA); with literatures painstakingly reviewed and the results obtained from the analyses meticulously interpreted, the following inferences were drawn from the research.

- MCA is a good pozzolanic agricultural waste as evident in the sum of its oxide ($SiO_2+Al_2O_3+Fe_2O_3=83.03$) which is more than the value stipulated by ASTM C618 1978; BS 8615-1 2019
- The optimum calcined temperature where the highest summation of the three major oxides (SiO_2; Al_2O_3 and Fe_2O_3) was obtained was at temperature of 800^0C for the MCA.
- MCA can belong to different classes of pozzolans (N, F and C) depending on the calcining temperature of the sample.
- MCA calcined at 800^0C, 700^0C, 600^0C and 500^0C belongs to Class N while MCA at 400^0C calcining temperature belongs to Class C based on the summation of the three major oxides (SiO_2; Al_2O_3 and Fe_2O_3).
- MCA is more thermal conductive than that of Ordinary Portland Cement (OPC), and the thermal conductivity of MCA varies with calcining temperature.
- MCA calcined at the optimum temperature, 800^0C calcining temperature has a pH value of 8.9 which is not negating what Is stipulated in ASTM C618 1978
- From the aforementioned, MCA will suitably perform satisfactorily when used as cementitious materials in lieu of cement in concrete. This can be corroborated through the compressive strength of concrete cube made using MCA as the sum of the oxides as calculated using the Bogue's compounds can be helpful in assessing the rate of hydration and the degree of strength development.

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