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Research Paper

Performance of Corncob Ash Pozzolan in Concrete Samples

Olaleye O.T
Department of Civil Engineering, MoshoodAbiola Polytechnic, Abeokuta, Nigeria

Abstract: *This study examined the performance of corncob ash (CCA) pozzolan in the production of concrete samples. CCA are burnt and heated in an electrical furnace at temperature of 700^0 C kept there for 2 hours, analysed the ash to confirm its pozzolanity index. The ash are sieved and partially substituted at 10, 20 and 30% by weight of cement to cast concrete samples. Structural performance test carried out on forty – eighty samples of concrete cubes of 150 mm and equally on 150 * 150 * 500 mm reinforced concrete beams mixed in the ratio of 1: 2: 4 with 0.5 water/cement ratio. Samples are cured in water for 28, 60, 90 and 120 days. Test for chemical composition and analysis of CCA is carried out, test of compressive strength, flexural strength; deflection and experimental crack width test are performed. The chemical analysis of the ash contained the combine silica, alumina and ferric oxides resulted in 74.3% which suggested the CCA to be of class F pozzolan. Compressive strength result at 28 days testing was 20.56, 17.05 and 13.5 N/mm^2 compared to 22.52 N/mm^2 of the control while the flexural strength was 23.1, 21.57 and 16.37 N/mm^2 respectively as against 24.1 N/mm^2 of the control. The load – deflection curves of the ash blended concrete beam at 10% ash gave the deflection of 14 mm with failure load of 110.2 kN compared to the control deflection of 17 mm at failure load of 119.6 kN. The crack width of the closest samples was the 10% ash of 13 mm width compared to the control of 6.8 mm as observed from the test which showed that the ash blended concrete developed low strength and less resistance to deflection, but over time produced increase in strength of concrete members. The work revealed that the corncob ash blended concrete produced low strength samples. The performance in concrete structure though very low but could be used up to 10% ash.*

KEYWORDS: *Pozzolan, compressive strength, flexural strength, deflection, crack width*

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I. INTRODUCTION

1.0 Pozzolans

Sometimes during the second century, the Romans quarried a volcanic ash mixed with lime and found the mixture to be much stronger than what they had produced previously [1], the ash was analyzed and found that it contained silica and alumina which when combined chemically with lime, produced what could be pozzolanic cement. According to [2], a material could be considered pozzolanic if it contains a minimum of 70% of combined Silica (SiO_2), Alumina ($Al_2 O_3$) and Ferric Oxide (Fe_2O_3) [1].Industrial and agricultural by-products such as fly ash (FA), rice husk ash (RHA) and corncob ash (CCA) are now widely used as pozzolans in concrete since their uses generally improve the properties of the blended cement [3]. [4] Studied the use of CCA to produce concrete specimen and concluded that the compressive strength improves with ages.

These industrial or agricultural by products or waste are generated by pyrolysis or combustion to get the ashes that have pozzolanic properties. According to [5], the thermal conversion of waste can be in form of simple combustion, pyrolysis and gasification, and all three can be present in the same process depending on the path of the mass-loss kinetics. The temperature-decomposition profile and the kinetics of its thermal decomposition are rapidly determined by thermogravimetry. According to [6], the corncob is burnt to ashes at temperature below 500 - 700^{O}C to maximize the content of armophous silica. Simple open air burning typically occurs between 500^{O}C to 600^{O}C [7]. These ashes are used with cement to form blended cement.

According to [8] blended cement (BC) is defined as blended hydraulic cement made by intergrinding Portland cement with another pozzolans or cementitious materials such as fly ash, blast furnace slag and condensed silica fume. [9] indicated that the development and use of BC was growing rapidly in the concrete industry due to their technical and financial benefits. [10] investigated the properties of BC that contained 34% type II OPC with 66% slag, and found better performance in terms of strength and durability.

According to [11], the test result of compressive strength of FA mixed concrete showed that strength development of FA mixed concrete is slow at earlierstage but equal or more than that of OPC concrete. Up to 40% replacement, [11] obtained greater result compared to OPC concrete at the age of 90 days. In the study of Bouzoubaa et al (2001), a similar trend was observed. However, [12] found a greater result for 15% replacement at the 56 days. Therefore, FA replacement in concrete would be remarkable cement saving as well as minimizing steps for the construction of concrete structures without sacrificing the strength of concrete.

[3] investigated that the 28 days flexural strengths of the control concrete made with the Laboratory Produced Cement (LPC) and the commercially available (Type III) cement were 6.3 and 6.7 MPa respectively, the corresponding strengths of the concrete made with LPC in which fly ash had been batched separately, and that of the blended cement using the FA were 4.0 and 5.1 MPa respectively. They also reported that the 28 – day splitting strength for all the concretes were approximately 3 MPa except for a mixture 2.2 MPA. The aforementioned results show that the use of high volume FA blended cement improves flexural and splitting tensile strength of concrete and this increase was due to an increase in the fineness of the fly ash and the LPC in the blended cement resulting from the intergrinding of the two components.

Strength development of FA mixed mortar was investigated by [13], OPC was partially replaced by 20 and 40% with ground palm oil fuel ash, ground rice husk and classified fuel fly-ash in a research. They found that compressive strength of cement pastes similar to 20% replacement of pozzolan but in the case of 40% dosage, a significant strength decreasing trend were observed with an increment in the replacement of pozzolans at the age of 7 days. But, at the age of 28 days, the strength of pastes containing pozzolans, were approximately the same as that of OPC paste. Different results were found at 90 days, the strength of paste containing pozzolans were slightly higher than that of OPC pastes by up to 6 MPa. This greater strength development character at later age exhibits the characteristics of pozzolanic materials. Therefore FA replacement in mortar and concrete would be remarkable cement saving as well as cost minimizing steps for the construction of concrete structures without sacrificing the strength of concrete. It was summarized that FA could perform an imperative role as a supplementary alternative of cementing material in concrete construction [9].

These works intended to produce corncob ash (CCA), analyzed the ash and used it to produce concrete of ratio of 1: 2: 4, water cement ratio 0.5 and partly use it to substitute cement at 10,20 and 30%, cured in water for 28, 60 and 120 days to perform compressive, flexural strength, determine deflection and experimentally determine crack width of the beams.

II. Materials and Methodology

2.1 Materials and specimen preparation

Corncobs were collected and pre – burnt in an incinerator to reduce the volume of shaft and subjected to further heating in an electrical furnace, calcined to 700^0C, kept at this temperature for 2 hours and furnace switch off and allows cooling at room temperature. The ash was further ground and sieved with 0.063 mm size into fine ash.

2.2 Method of batching

Concrete of mix ratio 1: 2: 4 was batched with 0.5 water cement ratio. The binder portion contains 10, 20 and 30% of the weight of cement as CCA. The mixing was done manually on a clean concrete floor and the materials were thoroughly mixed in the dry state, after which water was added gradually until the water weighed had been used. Mixing of the concrete specimen was done by turning the mixture of binder (cement + CCA), water and aggregate until the concrete was uniform in color and consistency. Forty eight numbers of concrete cubes of size 150 mm were cast and concrete beams of 150 x 150 x 500 mm were equally cast and reinforced with 4Y12 mm links of 6 mm at 100 mm centre to centre fig. 1. Both the concrete specimens (cubes and beams) were cured in water for 28, 60, 90 and 120 days.

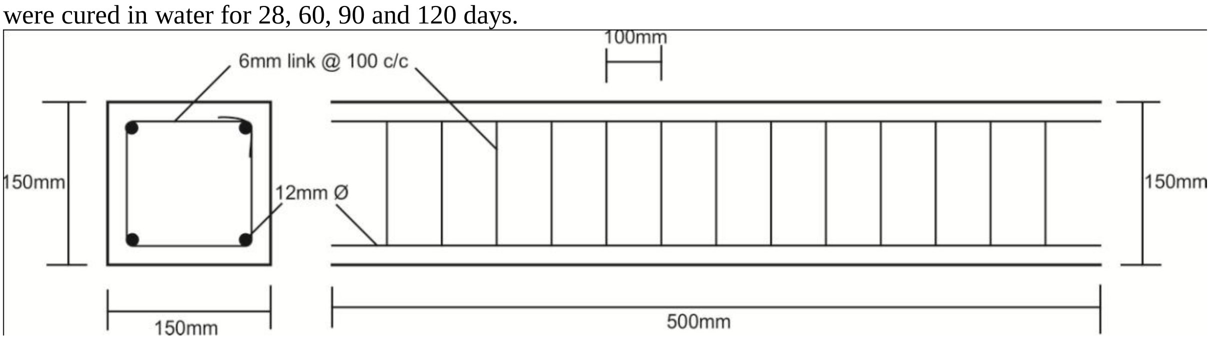

Figure 1: Cross and longitudinal section of reinforcement used for beam specimen

Table 1: Mix proportion for concrete cubes and beams

Admixture Type	Cement (kg)	Corn cob ash (kg)	Sand (kg)	Aggregate (kg)	Water (kg)
100% OPC	78.17	0	156.44	313	46.93
10% CCA	70.4	7.83	156.44	313	46.93
20% CCA	62.56	15.66	156.44	313	46.93
30% CCA	54.73	23.49	156.44	313	46.93

2.3 Testing of specimen

Compressive strength of the concrete cubes was determined at the end of each curing period of 28, 60 90 and 120 days using fig. 2, while flexural strength of the beam was equally determined fig. 3 at 28 and 60 days.

Figure 2: Cube strength test

Figure 3: Flexural strength test

III. Result and Discussion

3.1 Chemical composition of CCA

Considering the chemical composition shown in Table 2, the combination of the silica, alumina and ferric oxides i.e. SiO_2, Al_2O_3 and Fe_2O_3 is 74.3% with low LOI of 6.93%, these properties suggested that the ash could be a pozzolan. According to ASTMC 618, when thesum percent of SiO_2, Al_2O_3 and Fe_2O_3 exceed 70%, and loss on ignition (LOI) less than10%, the ash belongs to class F and generally it is seen that class F ash contains a low content of CaO.

Table 2: Chemical and percent composition of corncob ash

Chemical constituents	Sample1 %comp.	Sample 2 % comp.	Sample 3 % comp.	Average % comp.
CaO	1.69	1.67	1.68	1.68
MgO	0.87	0.86	0.90	0.89
Na_2O	0.61	0.64	0.59	0.67
K_2O	2.13	2.20	2.10	2.14
Fe_2O_3	3.21	3.29	3.19	3.23
SO_3	0.58	0.59	0.55	0.57
Al_2O_3	7.25	7.18	7.15	7.19
SiO_2	63.85	64.25	63.55	63.88
LOI	6.94	6.95	6.90	6.93

3.2 Compressive strength of concrete

Figure 4 shows the compressive strength of concrete cubes increased as the curing age increased and decreased as ash content increased. For instance the strength of control samples at 28 days was 22.52 N/mm^2 while at 10% ash content reduced to 20.56 N/mm^2, at 20%, 17.05 N/mm^2 and at 30% was 13.54 N/mm^2

3.3 Flexural strength of concrete

The determination of flexural strength (modulus of rupture) is essential in estimating the load carrying capacity of beams at which the concrete members might crack; this test was useful in the design of slab and airfield runways. The results of flexural strength are shown in fig. 5; it was observed that flexural strength increased as the curing age increased while reduced with increase in the ash content. The modulus of rupture at 28 days was 24.1 N/mm^2 for the control, at 10% ash was 23.96 N/mm^2, at 20%, 21.57 N/mm^2 and 30% was 16.37 N/mm^2 shows that modulus of rupture decreased as the ash increases. However, an important pozzolan characteristic is the slow development of strength which implies that at 10 and 20% corncob ash concrete might develop the required strength over a period of time.

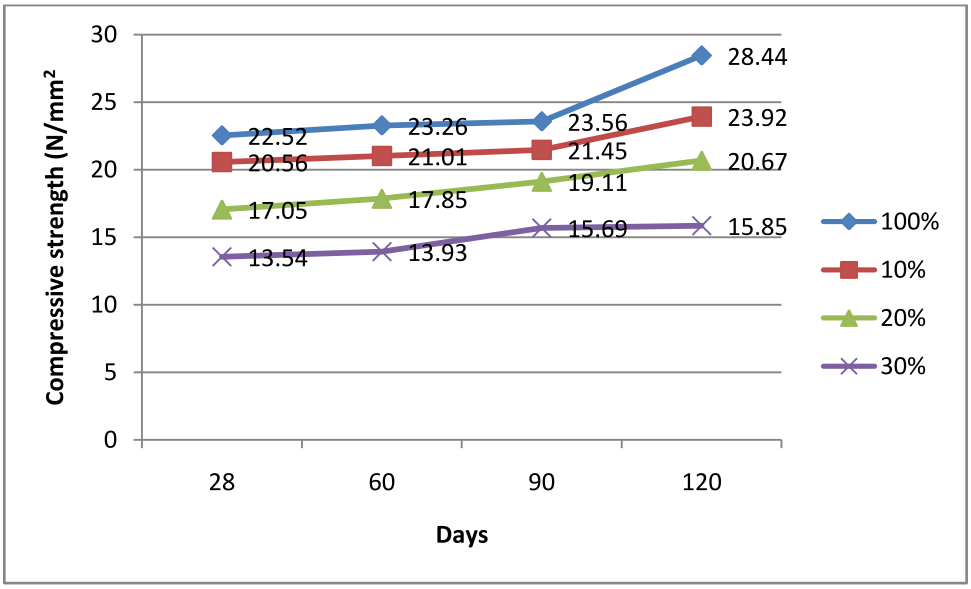

Figure 4: Compressive strength of CCA mixed concrete

3.4 Deflection and crack width of beams

Fig. 6 shows average deflection measurements taken at every 10 kN load exerted and recorded. The resistance of the reinforced concrete beam to the applied load causes deflection and resulted in cracks and eventual failure of the beam. These cracks were measured with calipers and experimentally determined, the resulted cracks were from the support to the point load area denoting shear failure at support Fig 3.

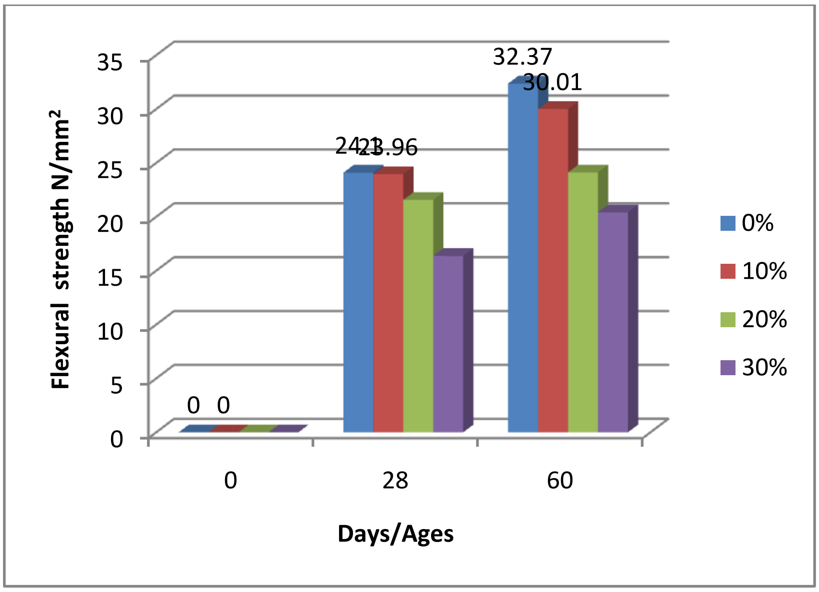

Figure 5: Flexural strength of beam

At 0% ash, the failure load 119.6 kN with a deflection of 17 mm, resulting in the average experimental crack width of 6.8 mm, compared to the closest 10% CCA ash failure load of 110.2 kN, deflection of 14 mm with the average experimental crack width of 13 mm Table 3 and fig. 6. But as the ash concentration increases the failure load decreases, deflection reduces and more crack width widened exhibiting low resistance to the applied load confirming low strength of the ash disposed concrete.

Table 3: Failure load and average experimental crack width of beams

Percentage replacement (%)	Failure load (kN)	Average experimental crack width (mm)
0%	119.6	6.8
10%	110.2	13
20%	96.1	31
30%	94.3	34

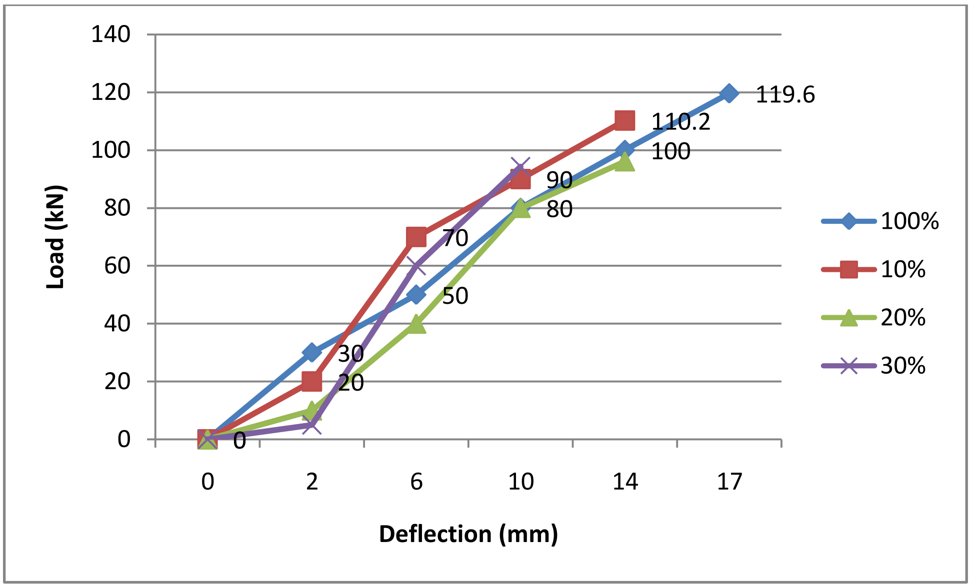

Figure 6: Load-Deflection curve of CCA mixed concrete beams

IV. Conclusions and Recommendation

4.1 Conclusions

- The corncob ash contained 74.3% of the combined silica, alumina and ferric oxides which made it to belong to class F pozzolan.

- Compressive strength performed at 10, 20 and 30% ash at 28 days strength was 20.56, 17.05 and 13.5 N/mm^2 of 22.50 N/mm^2 of control while the flexural strength was 23.96, 21.57 and 16.37 N/mm^2 respectively of 24.1 N/mm^2 of the control resulted in low strength of ash composed samples.
- The load – deflection curve of the tested samples of 10% ash showed less resistance to failure load of 110.2 kN with deflection of 14 mm compared to that of the control of 119.6 kN at 17 mm respectively.
- While the average experimental crack width observed of the tested samples at 10% ash was 13 mm more than the control of 6.8 mm, which showed that the ash composed beam developed low strength.

4.2 Recommendation

Corncob ash is of class F pozzolan and the performance in concrete structure produced low strength but over time developed strength which could be tolerated up to 10% ash.

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