2024
September coou African Journal of Environmental Research *Vol 5, No. 2, 2024. pp 113-129*

EFFECT OF CORN COB ASH AND LOCUST BEAN POD ASH ON THE MECHANICAL PROPERTIES OF CONCRETE

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Abstract

The Portland cement production is a highly energy-intensive process and the current trend in concrete research is towards finding alternative materials that can partially or fully replace cement. Supplementary cementitious materials (SCM) are important in producing high-strength and high-performance concrete. This study aims to investigate the effect of corn cob ash and locust bean pod ash on the mechanical properties of concrete. The concrete mix of 1:2:4 and a water cement ratio of 0.5 was blended with 5–30% pozzolanic materials individually and combined, and the concrete cured at 7, 14, 28 and 56 days. The specific gravity of Corn cob ash (CCA) and (Locust Bean Pod Ash) LBPA is 2.25 and 2.33 respectively. Corn cob ash and locust bean pod ash are pozzolanic material having satisfied the requirement of ASTM C618-05. It is observed that the workability of fresh concrete is reduced as the dosages of CCA and LBPA increase in the mixture. Moreover, the compressive and flexural strengths at 10% of CCA or CCA/LBPA gave similar strength with the control concrete, at 28 and 56 days respectively. Furthermore, the density and water absorption of concrete were reduced with increasing percentage of CCA and LBPA in concrete. It can be concluded that 10% CCA and LBPA as replacement of cement, results in improved performance of concrete. The research recommends that 10% CCA and LBPA as cement replacement individually or in the blend are the optimum percentages for structural applications which will lead to strong and quality concrete, and also help reduce the use of cement.

Keywords: Compressive Strength, Corn Cob Ash, Flexural Strength, Locust Bean Pod Ash, Mechanical Properties

INTRODUCTION

Concrete is produced by mixing cement, aggregates, and water in a precise ratio based on the desired performance characteristics. Admixtures are optional materials that can be added to change the final physical attributes or the placement and curing processes (Agboola, *et al.,* 2023; Orame *et al.*, 2020). Donome and Illston (2010) claim that concrete is a versatile material whose use and application, along with its accessibility, have guaranteed its continued and growing significance for all forms of construction worldwide. When concrete is still fresh, it can be shaped into any shape. Concrete, according to Harris (2006), is a stone like material created by combining water, cement, fine aggregate and coarse aggregate in a mix. The mixture is then allowed to dry and harden. It is the most commonly used building and civil engineering construction material, but it is relatively new compared to materials like stone, wood, steel, etc (Garba, 2008). Neville (2010) defines concrete as any mass or product created by the application of a cementing media, which is often the result of a reaction between water and hydraulic cement. While some materials will harden into artificial rocks with the help of cement, additional ingredients in concrete improve its strength, make the new material workable, and ensure durability (Agboola, *et al.,* 2021a). Concrete, which consists of cement, water, and typical fine and coarse aggregate as its essential constituents, is a fundamental construction material utilised to meet the housing and infrastructure needs of society. It has been a top building material for over a century, and the yearly global production rate is thought to reach one million cubic meters (Neville, 2003).

On the other hand, excessive concrete use leads to overburden and increased cement and aggregate demand (Mamman, *et al.,* 2020; Agboola *et al.,* 2021b). An important component of concrete manufacturing, cement produces large emissions of greenhouse gases that deplete the ozone layer and degrade the environment. Compared to other concrete ingredients like gravel, sand, water, etc., it is also more costly. One ton of cement requires about 125 litres of fossil fuel and 118 KWH of energy to produce (Vazinram & Khodaparast, 2009). This indicates that burning fuel is necessary for the manufacturing of cement, which releases a significant amount of carbon dioxide (CO_2). Research on cement substitutes or alternatives that will completely or partially replace cement in the construction sector has been spurred by the issues of cost and pollution (Agboola, *et al.,* 2020b; Ogunbode & Hassan, 2011). The global production of Portland cement surpasses 2.6 billion tons annually, with an annual growth rate of 5% (Soomro, *et al.,* 2023; Khozin, *et al.,* 2020; Jindal, 2015). This results in the emission of roughly 7% of carbon dioxide (CO_2) into the atmosphere, a major contributor to global warming. According to Yoro, *et al.* (2020); Al-Ghussain, (2019), Yang, et al. (2019) and Hansen, *et al.* (2000), up to 65% of global warming is caused by CO_2. As a result, researchers have worked to lessen the issue caused by the use of Portland cement in the production of concrete by substituting some of its quantity with other cementing materials, such as fly ash, ground granulated blast furnace slag, rice husk ash, corn cob ash, metakaolin, groundnut husk ash, volcanic ash, and glass waste powder (Agboola, *et al.,* 2020a; Rahmat *et al.,* 2024). Agboola *et al.* (2020c) Duchesne, (2021) Juenger, et al. (2019) and Dadu (2011) state that to increase the strength and durability of concrete, less Portland cement is now used in concrete mixtures in favour of less expensive pozzolans and Supplementary Cementitious Materials (SCM). The potential for using industrial by-products and agricultural wastes as cementitious materials was discovered during the hunt for alternative binder or cement replacement sources. This material's pozzolanic qualities improve and provide an advantage to the final concrete's properties (Agboola, *et al.,* 2020b).

According to the American Society for Testing and Material (ASTM C125-06), pozzolan is a siliceous or siliceous and aluminous material that, has little or no cementitious value itself but in finely divided form and the presence of moisture, will chemically react with calcium hydroxide at room temperature to form compounds with cementitious properties. Pozzolan was categorised into two by Shetty (2009), as artificial and natural. Natural pozzolans consist of volcanic ash, pumicites, opalinc cherts, diatomaceous earth, clay and shales, and volcanic tuffs. Fly ash, blast furnace slag, silica fume, corn cob ash, rice husk ash and groundnut husk are a few examples of artificial pozzolans. Corn cob ash and locust bean pod ash are two of the many supplementary cementitious materials used in concrete; they are readily available, easily obtained, sustainably produced, and environmentally benign. Corn cob is an agricultural waste product obtained from maize or corn. The Food and Agriculture Organization (FAO) reports that the world produced 589 (million tons) of maize in 2000. The United States was the largest maize producer having 43%, of world production. Africa produced 7% of the world's maize. Nigeria was the second largest producer of maize in Africa in 2001 with 4.62 million tons with South Africa having the highest production of 8.04 million tons that year. The African locus bean tree (Parkia biglobosa) yields the fruit, which is the source of locus bean pods (makuba), a Waste Agricultural Biome (WAB) that may be widely and suitably utilized as a pozzolana for concrete production. Under the scientific name Parkia biglobosa, the African locust bean tree (Family Legumianosae: Mimosodeae) is a deciduous tree that can reach a height of 20 meters. The tree is often found in Nigeria and thrives throughout most of sub-Saharan Africa (Ntui, e*t al.,* 2012). It produces big fruit pods filled with valuable black seeds and delicious yellow pulp. When fermented, the seeds (Hausa: Dadawa, Igbo: Ogiri Yoruba: Iru) are used as a spice, for meals (Gernah, *et al.,* 2007).

Additionally, the tree's many parts have therapeutic uses (Ikhimalo, 2019; Nyadanu, *et al.,* 2017; Builders, 2014; Udobi, & Onaolapo, 2009). Typically, the brown pod is peeled off to reveal the fruit and seeds, then discarded as waste material. The usage of locust bean pod waste as a building material results from its economic benefits as an agricultural waste material that also poses a nuisance to the environment. According to research, using the pod extract as a binder increased the laterite blocks' compressive strength by 78.5% (Aguwa, & Okafor, 2012). Makuba could be a cheaper alternative if found to be mechanically suitable, owing to the relative abundance of the raw material even as the locust bean tree is being cultivated over a wide area within the African country (Saleh, 2015; Yusuf & Jimoh, 2012). The incorporation of pozzolanic waste ash in concrete can significantly enhance its basic properties in both the fresh and hardened states (Agboola, *et al.,* 2022a; Chandra 1997). These materials known as pozzolana greatly improve the strength and durability of concrete (Agboola, *et al.,* 2020c). The utilization of pozzolanic material from byproducts as the partial replacement of cement has important economic, environmental and technical benefits such as the reduced amount of waste materials, a cleaner environment and reduced energy requirement in cement production (Agboola, *et al.,* 2022b). The most important single property of concrete is strength. This is because the major aim of structural design is that the structural elements must be capable of carrying the loads imposed on them. Strength is also important because it is related to several other important properties that are more difficult to measure directly, and a simple strength test can indicate these properties such as durability (Peter & John, 2010). This research work therefore assesses the effect of corn cob ash and locust bean pod ash on the strength properties of concrete.

MATERIALS AND METHODS

Materials

Portland Limestone Cement was used for this research as the main binder, and it satisfies the minimum requirement as provided by BS 12 (1996). The Portland Limestone Cement brand was that of Dangote. Corn cob ash and locust bean pod ash were obtained from farmers in Maiduguri Borno State and were both burned at a controlled temperature of $600^{O}C$. Portable water fit for drinking was used in this research for mixing and production of the concrete specimens. River sand was obtained from suppliers in Bauchi town and used for the experiment. It was kept in the SSD condition before use in the laboratory. Sieve analysis following BS 933 part 1(1997) was carried out to distribute the particles in their required sieve sizes and remove impurities and bigger-sized aggregates. The coarse aggregate was obtained from suppliers in Bauchi town. Sieve analysis was carried out following BS 933 part 1(1997) to distribute the aggregate into various sieve sizes. The aggregate required comprises 20mm as its maximum and 5mm as its minimum size and they are used in the Saturated Surface Dry (SSD) condition.

Laboratory Tests

Specific Gravity: In determining the specific gravity, a pycnometer (a vessel of 1 liter capacity with a metal conical screw top and a 5mm diameter hole at its apex, giving a water tight connection), tray, scoop, drying cloth and weighing balance were used. The test procedure was carried out in accordance with BS 812-1377 (1970). The specific gravity was calculated using Equation 1.

$$Gs = \frac{(C-A)}{(B-A)(D-A)} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Where: A is the weight of an empty density bottle
B is the weight of an empty, density bottle plus water
C is the weight of empty density bottle plus the sample
D is the weight of empty density bottle plus water and sample

Density Test: This was carried out before crushing the concrete specimen. At the end of each curing period, the concrete specimens were weighed using an electric weighing machine balance. Density is calculated as the mass of concrete specimen in (kg) divided by the volume of concrete cube (m^3) and expressed in kg/m^3. Density tests were conducted on 100 x 100 x 100mm cube specimens following BS EN 12390-7 (2000).

Compressive Strength Test of Concrete: The compressive strength tests were conducted following BS EN 12390-3 (2009). Cube specimens of 100 x 100 x 100mm were prepared. All the cube specimens were removed from the moulds after 24 hours of casting and cured by total immersion in water until the testing age. Cubes were removed from the curing medium and allowed to drip off and be at saturated surface dry condition before being tested for strength. A compressive strength test was carried out on the cube specimens at the curing ages of 7, 14, 28, and 56 days. The cement was replaced with pozzolana at 5% to 30%.

Modulus of Rupture: The modulus of rupture was determined by conducting a simple unreinforced beam test subjected to a point loading. The beam specimens were prepared, produced and tested following BS EN 12390-5 (2009) guidelines, and concrete was tested at 7, 14, 28, and 56 days. The test specimens were 100 x 100 x 500 mm beams and were tested under a single-point loading test. The modulus of rupture (Mr), involved measuring the width and depth of the specimen, as well as the length of the span on which the specimen was supported, and the maximum load applied to the specimen. Modulus of rupture (Mr) in N/mm^2 was computed using the Equation 2.

$$Mr = \frac{PL}{bd^2} \qquad \text{.......................... (2)}$$

Where L is the length in millimeters of the span on which the specimen was mounted, P is the maximum load in kilograms applied to the specimen, and b, and d, are the measured breadth and depth of the specimen, respectively.

Water Absorption Capacity Test: This test was conducted at the curing ages of 28, and 56 days following BS 1881-122:(1983). Specimens were tested for absorption capacity, and on each day of testing, three cubes each were placed in the electric oven to dry the specimens at 105^{0}C for 72 hours. The specimens were removed from the oven and allowed to cool at room temperature before determining the initial weight recorded as (W_1). The final weight was determined after the concrete specimen had been immersed in water for 30 minutes. It was removed and dried with a cloth; re-weighed and recorded as (W_2). Equation 3 was used to compute the absorption capacity for the specimens:

$$\text{Water Absorption Capacity} = WA = \frac{W2-W}{W1}\ x\ 100 \text{.......................... (3)}$$

Where: W_1 = Weight of the concrete sample after oven dry
W_2 = Weight of the saturated surface dry concrete sample

RESULT AND DISCUSSION

Physical Properties of Materials

The result of the specific gravity of coarse aggregate (gravel) used was determined to be 2.79. This is presented in Table 1. The result obtained falls within the specified range of specific gravities for coarse aggregates as stated by Shetty (2005) that the average specific gravity of coarse aggregate varies between 2.6 to 2.8. From Table 2 the specific gravity of fine aggregate (Sand) was determined to be 2.64. This falls within the specified range specified by BS882 of the specific gravities of fine aggregate, as 2.4 to 2.9. The specific gravity of corn cob ash (CCA) as shown in Table 2 was determined to be 2.08. This value is close to values determined in the studies done by Michael, (2016), who stated the specific gravity of corn cob ash as 2.55, and that of Oluborode, and Olofintuyi, (2015) who found the specific gravity of CCA to be 2.27. The result determined in this research is consistent with works done by previous researchers. From Table 2, the Specific gravity of LBPA was determined to be 2.33; this value is higher than the value in research work carried out by Osinubi, *et al.* (2016), who reported a value of 2.3.

Table 1: Physical properties: Specific Gravity of Materials

Materials	Specific Gravity (g)
Fine Aggregate	2.64
Coarse Aggregate	2.79
Cement	3.14
Corn Cob Ash	2.08
Locust Bean Pod Ash	2.33

Setting Time and Consistency Test of Materials

Figure 1 to Figure 3, shows the setting time and consistency of Portland cement/corn cob ash and locust bean pod ash paste. The setting time and consistency test correspond with ASTM 187 (1986) and conforms to the test carried out by Agboola *et al.* (2022a) and that of Ogunbiyi, Olawale, Alabi & Thanni (2017) for pozzolanic materials.

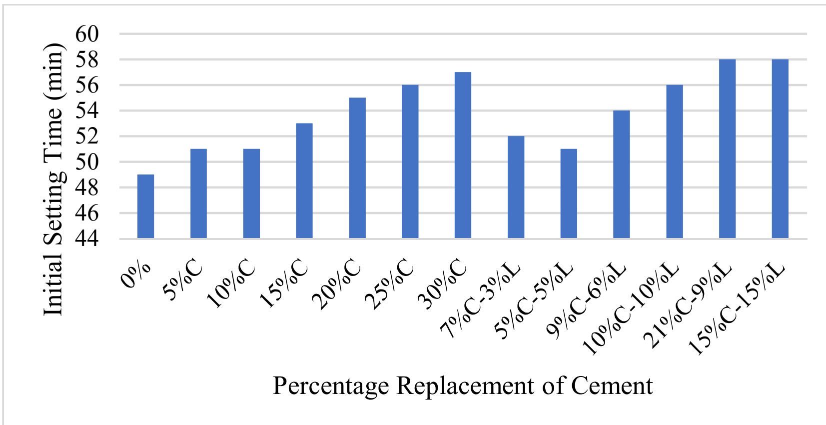

Figure 1: Initial Setting Time of Cement Mix

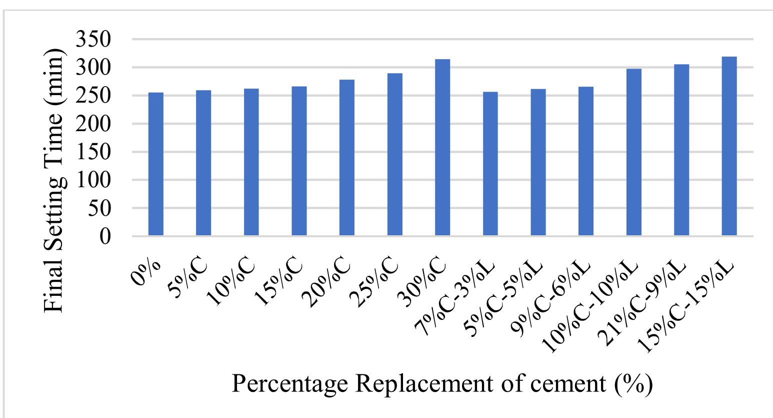

Figure 2: Final Setting Time of Cement Mix

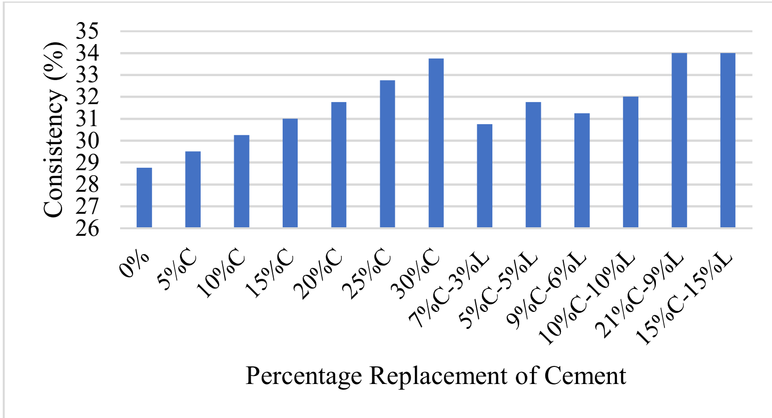

Figure 3: Consistency of Cement Mix

Chemical Composition of Corn Cob Ash

The chemical composition of corn cob ash used for this research indicated the silica, alumina and iron contents summed up to 75.06% as presented in Table 2 which is in line with Owolabi, *et al.* (2015) and Suwanmaneechot, *et al.* (2015) and satisfies requirement by the ASTM C618-05 which state that for a material to be a pozzolan the summation of Aluminum Oxide (Al_2O_3), Silicon Oxide (SiO_2) and Iron Oxide (Fe_2O_3) must be 70.0 % minimum.

Table 2: Chemical Composition of Corn Cob Ash in Comparison ASTM Requirement

Elements	% Composition
Aluminum Oxide (Al_2O_3)	17.53
Silicon Oxide (SiO_2)	53.62
Iron Oxide (Fe_2O_3)	3.91
Potassium Oxide (K_2O)	2.28
Calcium Oxide (CaO)	6.48
Sodium Oxide (Na_2O)	366
Magnesium Oxide (MgO)	1.17
Vanadium Oxide (V_2O_5)	0.006
Manganese Oxide (MnO)	0.11
Titanium oxide (TiO_2)	0.63
Chromium oxide (Cr_2O_5)	0.02
Zinc oxide (ZnO)	0.04

Chemical Composition of Locust Bean Pod Ash

The chemical composition of locust bean pod ash used for this research indicated the silica, alumina and iron contents summed up to 68.41% as presented in Table 3 which is in line with Adama, *et al.* (2013) and Ojewumi, *et al.* (2017).

Table 3: Chemical Composition of Locust Bean Pod Ash

Elements	% Composition
Aluminum Oxide (Al_2O_3)	14.67
Silicon Oxide (SiO_2)	41.48
Iron Oxide (Fe_2O_3)	12.26
Potassium Oxide (K_2O)	3.73
Calcium Oxide (CaO)	10.19
Sodium Oxide (Na_2O)	0.61
Magnesium Oxide (MgO)	2.33
Manganese Oxide (MnO)	0.41
Lead Oxide (MnO)	6.13
Sulphur trioxide (SO_3)	1.25

Workability Test

Figure 4 and Figure 5, present the results for the slump and compacting factor test of concrete made with corn cob ash and locust bean pod ash as partial replacement of OPC. From the values of the eight different mixes, the degree of workability for the slump test is low to middle workability according to Neville and Brooks (2010) and as specified by BS 1881-102. Mixes with 10% percent replacement of cement were higher than other replacements but had the same workability with 0% replacement (control). The slump test value for the Percentage replacement of cement decreases with an increase in pozzolana. It was observed that the best percentage at which the best slump can be obtained is when 10% of CCA-LBPA is used as a partial replacement for cement. For compacting factor test value, the degree of workability ranges from low to high which falls within the range specified by BS 1881-102 and Neville and Brooks (2010). Mixes with 0% - 15% show medium workability, while 20% and above shows low workability.

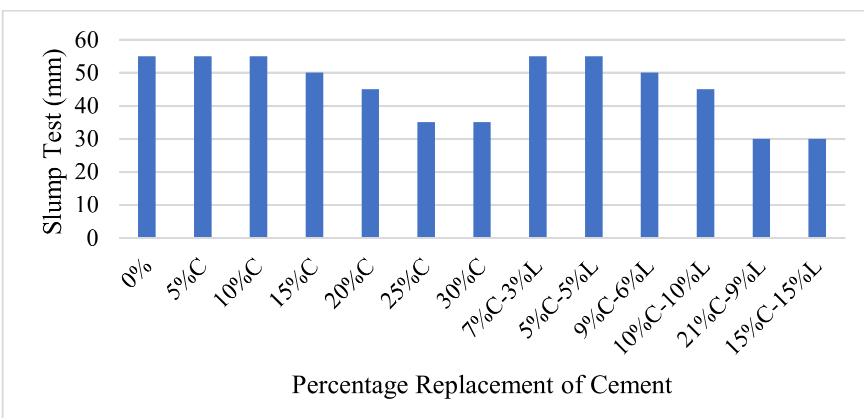

Figure 4: Slump Test of Concrete

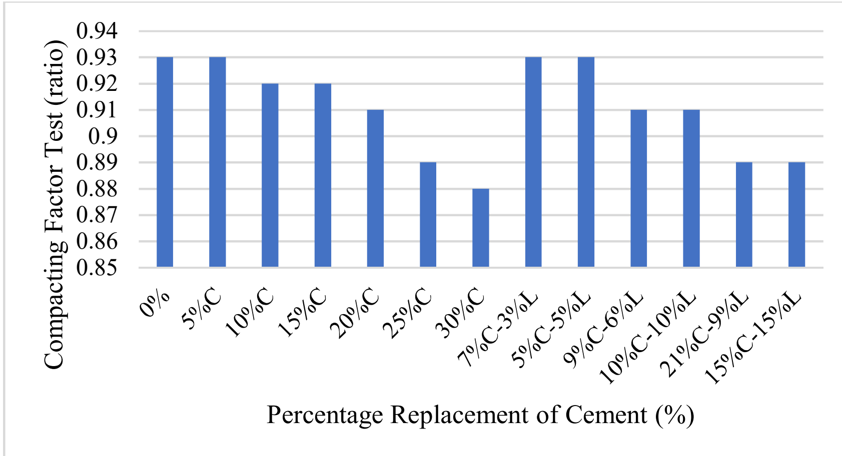

Figure 5: Compacting Factor Test of Concrete

Density of Concrete Cubes

Figure 6, presents the average density of concrete samples produced with corn cob ash and locust bean pod ash as partial cement replacement in concrete at 0%, 5%CCA, 10%CCA, 15%CCA, 20%CCA, 25%CCA, 30%CCA, 7%CCA/3%LBPA, 5%CCA/5%LBPA, 9%CCA/6%LBPA, 10%CCA/10%LBPA, 21%CCA/9%LBPA, 15%CCA/15%LBPA, cured at 7-, 14-, 28- and 56-days' hydration periods. The density of concrete cube samples varies from 2430 kg/m^3 to 2505 kg/m^3. Concrete samples with a density higher than 2600kg/m^3 are called higher density concrete samples (Kazjonovs *et al.,* 2010). The result shows that the higher the curing period of concrete the higher the density of the concrete.

However, concrete samples for this purpose are considered normal-weight concrete. Generally, the higher the density of concrete the lesser its porosity which ensures greater durability of concrete under heavy loads and harsh conditions. At 7 days' hydration period, the concrete sample with 5%CCA and 5%CCA/5%LBPA, shows the same density as the control concrete, while at 10CCA, 15%CCA, 7%CCA/3%LBPA, and 9%CCA/6%LBPA, shows improved density, however, the higher density values of concrete might be as a result of high compaction of concrete. After a 28-day curing period, 5%CCA shows the same density as that of the control concrete, the control concrete specimen shows better density than other replacement levels. There was loss of density in 25%CCA, 30%CCA, 15%CCA/15%LBPA, 21%CCA/9%LBPA, replacement of cement in concrete of about 1.76%, 2.16%, 1.60%, 1.36% respectively, as compared to the control sample at 28 days curing, and about 1.44%, 1.80%, 1.84%, 1.72% respectively, as compared to the control sample at 56 days curing. The result shows that the partial replacement of cement with corn cob ash and locust bean pod ash as a ternary mixture improves the density of concrete. The corn cob ash and locust bean pod ash substitution of cement, in the considered range, had some synergic effect on the density of cubes.

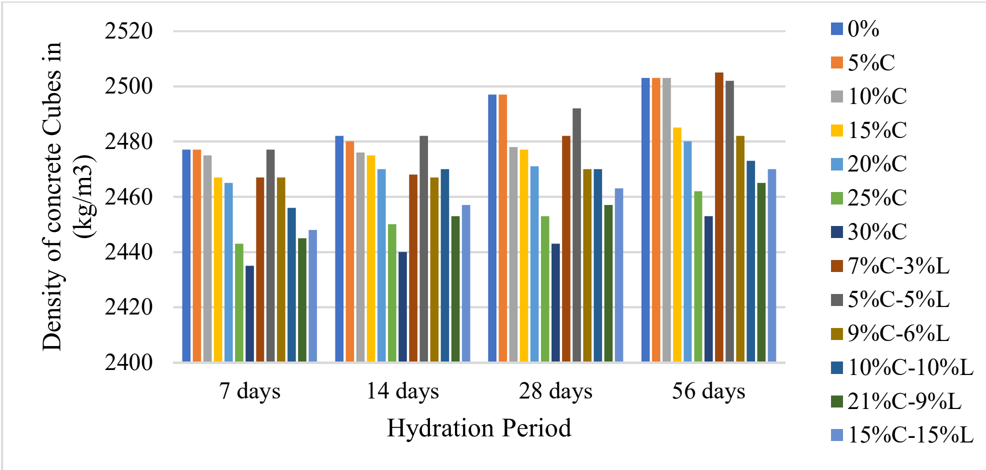

Figure 6: Density of Concrete Cubes

Compressive Strength of Concrete

Figure 7, shows the compressive strength of Portland cement/Corn ash-locust bean pod ash concrete specimens crushed at 7-, 14-, 28- and 56-days hydration periods. Samples of concrete with 0%, 5%CCA, 10%CCA, 15%CCA, 20%CCA, 25%CCA, 30%CCA, 7%CCA/3%LBPA, 5%CCA/5%LBPA, 9%CCA/6%LBPA, 10%CCA/10%LBPA, 21%CCA/9%LBPA, 15%CCA/15%LBPA as replacement of cement achieved strength of 14.6 N/mm^2, 14.1 N/mm^2, 14.2 N/mm^2, 14.0 N/mm^2, 14.0 N/mm^2, 13.1 N/mm^2, 12.3 N/mm^2, 14.5 N/mm^2, 14.5 N/mm^2, 14.1 N/mm^2, 13.9 N/mm^2, 12.5 N/mm^2, and 12.5 N/mm^2 respectively at 7 days. At 28days, concrete strength achieved 27.4 N/mm^2, 27.0 N/mm^2, 26.2 N/mm^2, 25.1 N/mm^2, 24.3 N/mm^2, 22.7 N/mm^2, 27.2 N/mm^2, 27.0 N/mm^2, 26.3 N/mm^2, 24.8 N/mm^2, 22.8 N/mm^2, and 22.7 N/mm^2 respectively for cement replacement in concrete at 5%CCA, 10%CCA, 15%CCA, 20%CCA, 25%CCA, 30%CCA, 7%CCA/3%LBPA, 5%CCA/5%LBPA, 9%CCA/6%LBPA, 10%CCA/10%LBPA, 21%CCA/9%LBPA, 15%CCA/15%LBPA, while the control concrete achieved a strength of 27.6 N/mm^2. This represents 0.72%, 2.17%, 1.45%, and 2.17% decrease of 5%CCA, 10%CCA, 7%CCA/3%LBPA and 5%CCA/5%LBPA replacement of cement in concrete respectively as compared to 0% control concrete in compressive strength. At 56 days' concrete strength achieved 28.7 N/mm^2, 28.7 N/mm^2, 27.8 N/mm^2, 25.1 N/mm^2 and 24.4 N/mm^2, 23.1 N/mm^2, 28.7 N/mm^2, 28.5 N/mm^2, 27.4 N/mm^2 and 27.0 N/mm^2, 22.9 N/mm^2, and 22.7 N/mm^2 respectively for cement replacement in concrete at 5%CCA, 10%CCA, 15%CCA, 20%CCA, 25%CCA, 30%CCA, 7%CCA/3%LBPA, 5%CCA/5%LBPA, 9%CCA/6%LBPA, 10%CCA/10%LBPA, 21%CCA/9%LBPA, 15%CCA/15%LBPA, while the control concrete achieved a strength of 28.9 N/mm^2. This represents 0.69%, 0.69%, 0.69%, and 1.38% decrease in strength of 5%CCA and 10%CCA, 7%CCA/3%LBPA, 5%CCA/5%LBPA replacement of cement respectively, as compared to 0% control concrete in compressive strength.

The result is in range with the work carried out by Obilade (2014). The result shows that at all ages, cement partially replaced with corn cob ash and locust bean pod ash has a significant effect on the strength properties of concrete. Improved strength in concrete could be due to the method of compaction used during the concrete production which aids good pozzolanic concrete performance. Agboola, *et al.*(2021a); and Jayswal and Mungule (2023) reported that cement blended with pozzolanas would produce 65 to 95 % strength of OPC concrete in 28 days.

Further, they reported that strength normally improves with age since pozzolanas react more slowly than cement due to different chemical compositions and properties. This behavior was also confirmed by Sengul, *et al*. (2005). Specimens containing up to 20% CCA had a compressive strength of 25.1 N/mm^2, while specimens with 10% CCA/10%LBPA had a compressive strength of 24.8 N/mm^2, however, both exceeded 65% of the 28 days compressive strength (27.6N/mm^2). Based on the above and the result obtained from this work, 10% ash and 90% cement can be suitable for use in concrete. 15% cement replacement can also satisfy conditions for structural requirements; however, 10% cement replacement is optimum.

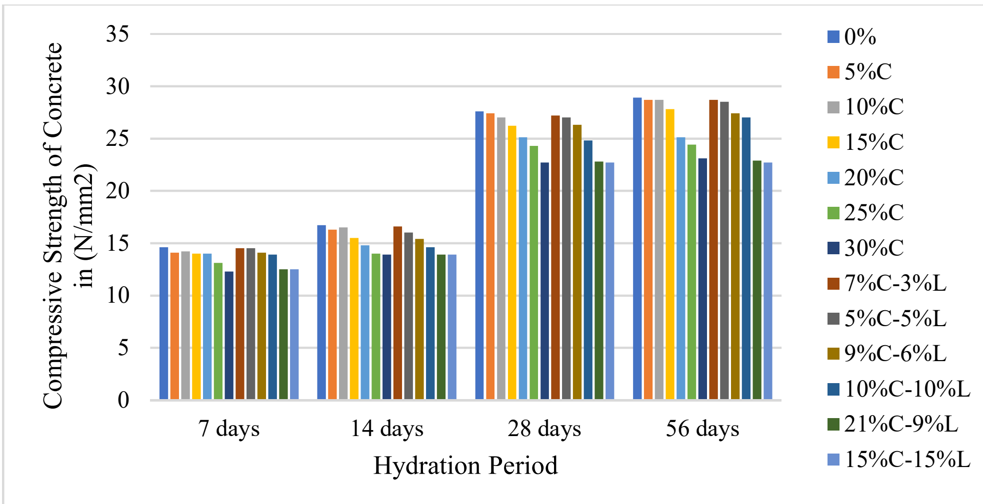

Figure 7: Compressive Strength of Concrete Cubes

Flexural Strength

Figure 8 presents the flexural strength of OPC/CCA-LBPA specimens tested at 28 and 56-day hydration periods. Concrete specimens with 0% replacement achieved 4.86 N/mm^2 while 5%CCA, 10%CCA, 15%CCA, 20%CCA, 25%CCA, 30%CCA, 7%CCA/3%LBPA, 5%CCA/5%LBPA, 9%CCA/6%LBPA, 10%CCA/10%LBPA, 21%CCA/9%LBPA, 15%CCA/15%LBPA replacement of Portland cement with corn cob ash and locust bean pod ash achieved 4.81 N/mm^2, 4.84 N/mm^2, 4.66 N/mm^2, 4.51 N/mm^2, 4.47 N/mm^2, 4.42 N/mm^2, 4.84 N/mm^2, 4.84 N/mm^2, 4.65 N/mm^2, 4.63 N/mm^2, 4.51 N/mm^2 and 4.48 N/mm^2 at 28 days. This represents 1.03%, 0.41%, 0.41%, and 0.41% decrease of 5%CCA, 10%CCA, 7%CCA/3%LBPA, and 5%CCA/5%LBPA, respectively in flexural strength compared to control concrete. The significant effect noticeable in the strength of the percentage replacement of cement in concrete could be a result of the type of pozzolana used in the production of the concrete.

However, the flexural strength increases with increased curing age. Replacement of cement with corn cob ash and locust bean pod ash at a 10% replacement level gives higher flexural strength as compared to other cement replacement levels because it makes good bonding and excellent filler between the aggregates and paste of the concrete. The findings of this study are related to those of Rahmat *et al.* (2024) that the flexural strength of concrete increases with an increase in curing days.

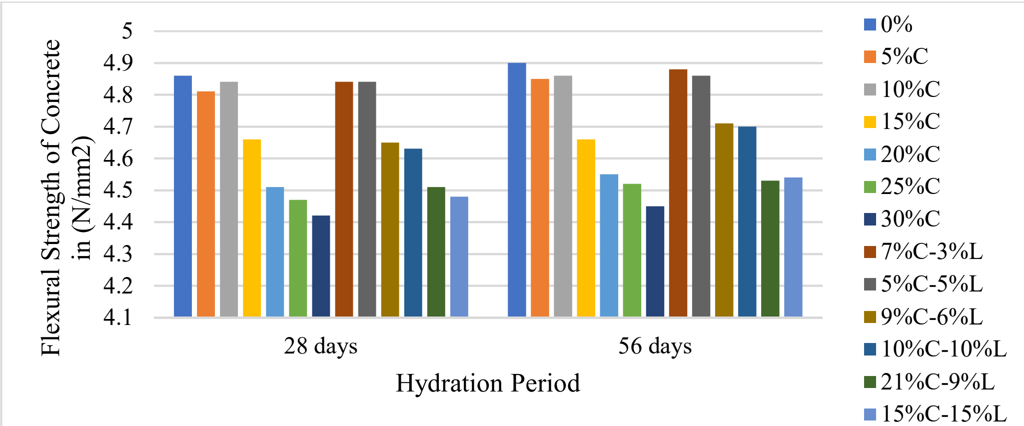

Figure 8: Flexural Strength of Concrete Beams

Water Absorption Test

Figure 9 presents the water absorption test of Portland cement/corn cob ash-locust bean pod ash concrete specimens tested at 28, and 56 hydration periods. The degree of absorption of the concrete specimen tallies with the work carried out by Pitroda and Shah (2014) and Agboola *et al.* (2022b) who stated that the average absorption of the concrete test specimens shall not be greater than 5%. The level of absorption of concrete samples reduced with an increase in curing days. Concrete samples with 0% replacement absorbed 1.71% while 5%CCA, 10%CCA, 15%CCA, 20%CCA, 25%CCA, 30%CCA, 7%CCA/3%LBPA, 5%CCA/5%LBPA, 9%CCA/6%LBPA, 10%CCA/10%LBPA, 21%CCA/9%LBPA and 15%CCA/15%LBPA absorbed 1.74%, 1.77%, 2.00%, 2.35%, 2.60%, 3.16%, 1.70%, 1.66%, 1.88%, 2.23%, 3.08% and 3.00% respectively. Also, at 56 days, Concrete samples with 0% replacement absorbed 1.63% while 5%CCA, 10%CCA, 15%CCA, 20%CCA, 25%CCA, 30%CCA, 7%CCA/3%LBPA, 5%CCA/5%LBPA, 9%CCA/6%LBPA, 10%CCA/10%LBPA, 21%CCA/9%LBPA and 15%CCA/15%LBPA replacement absorbed 1.66%, 1.71%, 1.82%, 2.18%, 2.41%, 2.96%, 1.61%, 1.62%, 1.73%, 1.99%, 2.88% and 2.81% respectively.

This means that 20% and below the cement's replacement level absorbed less amount of curing agent than higher cement replacement which is a result of less filler material available in the concrete specimen which is effectively mixed with cement. The result of this research is in line with the work of Agboola, *et. al.* (2021a) who stated that glass powder as a pozzolana in concrete is impermeable to water and that pozzolana improves the permeation characteristics of concrete.

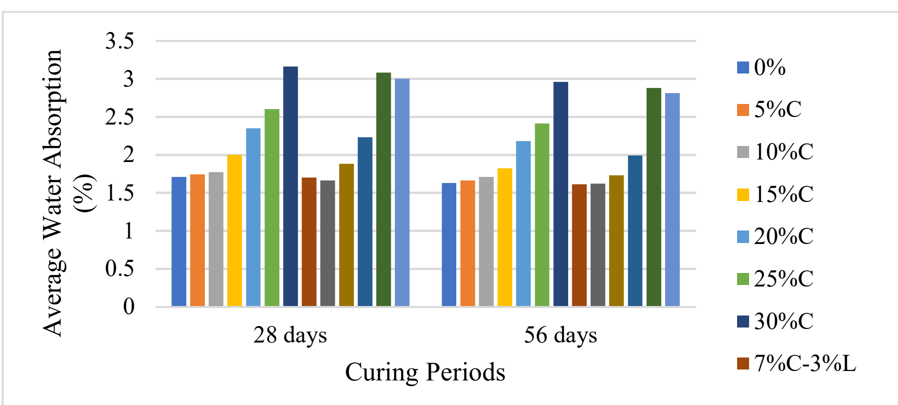

Figure 9: Water Absorption of Concrete

CONCLUSION

Corn cob ash and locust bean pod ash undoubtedly possess pozzolanic attributes and can partially replace cement in the production of concrete. Concrete strengths increase with curing age and decrease with increasing percentage of pozzolana. The strength of concrete is influenced by the pozzolanic reaction in the mix. The result indicated that concrete produced with corn cob ash and a combination of corn cob ash and locust bean pod ash at a lower replacement level tends to improve the strength of concrete. 10% pozzolanic concrete has the same strength index as the control concrete at 28 and 56 days. The flexural strength results revealed that concrete at all replacement levels met the expected 4.0N/mm^2 flexural strength of concrete at 28 days. Reduced compressive and flexural strengths of pozzolanic hardened concrete with an increase in percentage replacements may be attributed to the agglomeration of the pozzolana in hardened concrete. The research recommends the use of corn cob ash and locust bean pod ash to replace cement in concrete production due to their availability and viability. Corn cob ash and locust bean pod ash in concrete mix should be subjected to further evaluation in diverse environmental conditions, elevated temperature and further extended to 90, 120, 180, 360 or possibly 720 days to further determine the pozzolanic ability. The economic viability of the pozzolanic material in concrete should be evaluated. Research should be carried out on the effects of admixtures on the properties of corn cob ash and locust bean pod ash concrete, especially admixtures that may improve the curing of pozzolans in general and water enhancing admixture due to the high absorption of the pozzolanas.

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