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Research Article

Performance Assessment of Curing Techniques on Pozzolanic Concrete

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Abstract

The strength development of Portland cement concrete primarily results from the formation of ettringite and calcium silicate hydrates during hydration, which requires sufficient moisture. Effective curing is essential to maintain the moisture needed for this reaction, significantly influencing compressive strength. As such, researchers continue to explore optimal curing methods. Additionally, the use of pozzolanic materials as partial replacements for ordinary Portland cement has gained interest, though their hydration and strength development are also affected by curing techniques. This study investigates the impact of four curing methods i.e. ponding, sprinkling, covering with an impermeable membrane, and chemical curing on the strength development of five pozzolanic concretes incorporating groundnut shell ash (GSA), coal bottom ash (CBA), locust bean pod ash (LBPA), wood ash (WA), and metakaolin. Sixty cylindrical specimens (150 mm × 300 mm) were prepared, with three samples per curing method for each pozzolan, tested at 3, 7, 14, and 28 days. The results show similar strength across all curing methods at 3 days. However, as curing continued, significant strength differences emerged. Chemical curing consistently produced the highest compressive strength due to its superior moisture retention, followed by ponding, membrane covering, and sprinkling. Regardless of pozzolan type, strength increased with extended curing periods. The study concludes that adequate curing time is vital for strength development in pozzolanic concretes. Among the methods evaluated, chemical curing is the most effective, followed by ponding and membrane methods, with sprinkling being the least effective. These findings offer practical guidance for selecting suitable curing techniques to optimize pozzolanic concrete performance under standard conditions.

Keywords: Pozzolanic, Concrete, Curing, Cement, Strength.

Introduction

The use of pozzolanic components in concrete has gained significant increased in recent years, as it helps to increase the overall durability and sustainability of construction projects. A pozzolan is a siliceous aluminous material which chemically combines with calcium hydroxide in the presence of moisture to produce compounds that provide increased strength in concrete. Pozzolanic minerals tends to absorbs more water when added to a concrete mix, and this may delay the hydration process and affect the strength development of concrete. In this regard, appropriate curing techniques must be administered so that effective hydration process will be achieved.

Curing is an essential aspect of developing concrete's strength as it controls adequate moisture, temperature, and time for hydration to take place. Different curing techniques are adopted to avoid loss of moisture and enhance hydration in the pozzolanic concrete as water ponding, wetting, impervious materials, and chemical agents such as polyethylene glycol (PEG) among others. Curing could be done after the concrete has been placed in position or during the manufacture of concrete products, thereby providing time for the hydration of cement [1]. However, the effectiveness of these techniques has not been sufficiently studied in their application to the strengthening of pozzolanic concrete, and in the variation of the outcomes of strength with each technique. It is worth knowing that poor curing methods often lead to shrinkage and cause damage to the concrete.

Numerous researches have been carried out with focus on how effective curing methods are in relation to hydration of ordinary Portland cement containing pozzolana as partial replacement of cement in concrete. Raheem [2] compared effects of five (5) methods of curing on the compressive strength of Portland cement concrete and reported that, curing with moist sand produces the highest compressive strength amongst the curing methods. An investigation into the effect of curing procedures on properties of silica fume concrete revealed that steam curing better enhances the properties of silica fume concrete, whereas air curing exhibited adverse effects as compared to moist curing [3]. This gap indicates the necessity to investigate the efficiency of curing methods in the strength development of pozzolanic concrete. This study determines the effectiveness of various curing techniques with a view of selecting the one that best allows for hydration continuity in pozzolanic concrete. Thus, by assessing the viability of these curing methods, this study attempts to give recommendations for efficient strength development in pozzolanic concrete mixes with a view of improving construction practices.

Concrete

Concrete was defined by Neville [4], as any product or mass made by the use of cementing medium. Generally, this medium is the product of reaction between hydraulics cement and water. Concrete has four major constituents which are cement, fine aggregate, coarse aggregate and water. It has a high variability of material owing to being composed of a variety of different materials [5,6]. Due to its well-established mechanical properties such as compressive strength, it serves as a crucial construction material [7,8].

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Pozzolanic Concrete

Pozzolanic concrete is a type of concrete which consists of various materials which include Cement, Water, Aggregate (Fine and Coarse Aggregate) and Pozzolana. Its numerous advantages make it one of the most economical, versatile, and universally used construction material available. It is commonly used for building bridges, sewers, culvert, foundations, footing, piers, abutments, retaining walls, and pavements. The typical constituent of Portland cement is calcium oxide (CaO), silica dioxide (SiO_2), aluminium oxide (Al_2O_3), ferric oxide (Fe_2O_3), and sulphate (S) [9,10]. The construction sector has seen a huge consumption of cement with an estimated 3.5 billion tons used. In addition, it is estimated that there will be a substantial rise in cement consumption of 25% within a ten-year period under the usage context of concrete, and this is not eco-friendly because of carbon (iv) oxide emission [11]. The rising number of cement production and consumption activities raised concerns on its effects in the environment. It points to the need for incorporating sustainable cement which would entail the use of alternative materials to cement in the fabrication process, which is aimed at reducing emissions associated with the fabrication of cement [7]. Nevertheless, using pozzolanic and chemical admixtures in concrete mix design enhances performance but makes it difficult to control the properties of the resultant mixture. Such admixtures may be beneficial in improving the performance of concrete in certain ways. However, their use needs to be well thought out and accurately measured with respect to the intended mechanical characteristics of the material [12,13].

Portland Cement

Portland cements are also referred to as hydraulic cements, and they react and hardened chemically with the addition of water. Portland cement contains limestone, clay, cement rock and iron ore blended which are been heated to 1200 to 1500°C. Ordinary Portland cement is recognized as a major construction material throughout the world.

According to Standard Specifications for Portland cement, Portland cements are classified as:

- Type I: General purpose. For use when the special properties specified for any other type are not required.
- Type II: For general use, especially when moderate sulphate resistance or moderate heat of hydration is required.
- Type III: For use when high strength concrete is desired.
- Type IV: For use when low heat of hydration is desired.
- Type V: For use when high sulphate resistance of concrete is desired.

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Groundnut Shell Ash (GSA)

Groundnut is found in both the urban and rural areas of Nigeria. Groundnut shell is produced widely as a waste material after milling is done. The shell occupies 20-24 % of the rough groundnut harvested, although the ratio differs by variety. Its application in some parts of human life will enhance sustainability of the environment and economic development especially in the developing countries. The high cost of cement, used as binder, in the production of mortar, concrete and sandcrete blocks has led to many research focusing on viable alternatives. In addition to cost, high energy demand and emission of CO_2 which is responsible for global warming, and the depletion of limestone deposits are disadvantages associated with cement production.

Coal Bottom Ash (CBA)

The sustainability of electrical power generation through the combustion of coal necessitates the recoverability of combustion by-products such as bottom ash. Also, since coal bottom ash (CBA) serves as a constituent of Portland cement, its use will result in more environmentally-friendly sustainable cement production. The aim of the European Union is to enhance the resource efficiency and minimize the climate and environmental impacts by promoting the waste reuse and recycling, as the waste hierarchy contained in the European Waste Framework Directive 2008/98/EC (European Parliament, European Waste Framework Directive, 2008). The use of industrial waste materials in the manufacture of cement reduces energy used in the process, minimizes the release of CO_2 into the atmosphere, and ultimately improves the efficiency in waste management. Then, it is necessary to consider also new Portland cement substitutes as ground coal bottom ash for possible incorporation in such types of blended cements. Bottom ash and fly ash are produced as waste materials from combustion processes in coal power plants. While coal bottom ash is generally incorporated in concretes as sand and a few other miscellaneous applications, it is often landfilled [14]. The appropriate level of replacement of cement with coal bottom ash in concrete is 8% [15].

Locust Beans Pod Ash (LBPA)

Locust beans pod is an agricultural waste, from African locust bean fruit. Large quantities can be found across northern Nigeria during the harvest season. Across the globe, much research efforts in recent times are geared towards possible ways of recycling these wastes for reuse to keep the environment clean and safe [16]. The transportation, construction, and environmental industries have the greatest potential for reuse because they use large quantities of the earthen materials annually [17]. Locust beans pod, which is a waste agricultural biomass (WAB) obtained from the fruit of the Africa locust bean tree (Parkia Biglobosa), is the material resource required for the production of locust beans pod ash (LBPA). The harvested fruits are ripped open while the yellowish pulp and seeds are removed from the pods. The empty pods are the needed raw material.

The recommended percentage replacement of cement with locust beans pod ash is 5% in concrete. The pods make up 39% of the weight of the fruit while the mealy yellowish pulp and seeds make up 61% [16].

Wood Ash

Wood wastes are primarily consisting of fine particles matter which can easily get air borne by winds, and may cause respiratory health problems to the dwellers near the dump site or can cause groundwater contamination by leaching toxic elements in the water. As the costs of disposal of are rising and volume of ash is increasing, a sustainable ash management which integrate the ash within the natural cycles needs to employed. Extensive research is being conducted on industrial by products and other agricultural materials ash like wood ash which can be use as cement replacement in concrete. Also, the cement industry is one of the primary sources which release large amount of major CO_2 to the atmosphere, so utilization of such wood ash solves two-fold problem of their disposal and provide a viable alternative for cement substitutes in concrete. The recommended percentage replacement of cement with wood ash is 10% in concrete [18].

Metakaolin

Metakaolin is a controlled substance that is produced when pure or treated kaolinite clay is heated to a temperature between 650º C and 850º C. Then grounded to a specific surface area within the range of 700-900 m^2/Kg. Due to its characteristic properties, it is classified as high quality pozzolanic which is often combined with cement to produce concrete of high resistant. It serves to increase the im-permeability of concrete by filling all voids between the cement and particles when incorporated into concrete. The pozzolanic reactions transform the microstructure and surface chemistry of concrete including the hydration products within by utilizing the calcium hydroxide that is liberated and making more of the useful calcium silicate hydrate, thus more strength and less pores enhance better performance durability. Over all metakaolin admixed concrete mixes strength development over shoot the strength development of concrete. All the other mixes present below have an inferior performance to the mix with 15% metakaolin [19].

Materials and Methodology

In this research, concrete samples were prepared using PLC partially replaced with pozzolanas as the binding material. Five pozzolana materials were used to observe if there is any general trend in the effectiveness of a particular method of curing. Mix proportions were adopted from recommendations on the optimum replacement level with each pozzolana material. The materials and methods are further discussed in this section.

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Materials

The materials used in making the concrete cubes and curing it are cement, groundnut shell ash, locust beans pod ash, coal bottom ash, metakaolin, and wood ash, fine aggregate, coarse aggregate, water, and polythene, polyethylene glycol.

i. Cement: Dangote brand of cement obtained from Samaru market was used to carry out the test.

ii. Groundnut Shell Ash (GSA): the groundnut shell was gotten from a local market in Kano state, Dawanau market area of Dawakin Kudu local government, the groundnut shell ash was prepared at chemical engineering laboratory, with the use of furnace at 650ºc temperature for a period of 6 hrs and sieve through standard BS sieve No.200 (75 µm), and 5% of the ash was used to replace cement as recommended by Ademola (2013), the GSA has a very fine texture, and have a grey colour.

iii. Coal Bottom Ash (CBA): the coal bottom ash was gotten from Dangote cement manufacturing company at Ilaro Ogun state, the coal bottom was sieved through standard BS sieve No.200 (75 µm).and 8% of coal bottom ash was used to replace cement as recommended by Darcy (2009). CBA has a very fine texture, it have a black colour.

iv. Locust Beans Pod Ash (LBPA): the locust beans pod was obtained from Gwargwaje Market in Zaria, the locust beans pod ash was prepared at chemical engineering laboratory, where furnace was used at to prepare the ash, from the locust beans pod peel at 650 ºc temperature for a period of 6hrs, then allowed to cool before grinding, then the ash was sieved through a standard BS sieve No. 200. (75 µm).and 5% of the ash was used to replace cement as recommended by Ndububa, 2015. LBPA has a very fine texture. and have a grey colour.

v. Wood Ash: the wood ash was gotten from a restaurant at Amina Hostel, A.B.U Zaria, the Wood Ash was sieve through a standard BS sieve No.200. (75 µm). the wood ash after sieving has a fine texture, and 10 % of it was used to replace the cement, it has a grey colour.

vi. Metakaolin: the kaolin was gotten from Kankara local government, Katsina. and was fired (calcined) in a furnace under temperature of 850ºc for a period of 2 hrs, and grinded after firing, at chemical engineering laboratory and sieve through standard BS sieve No.200 (75µm). the metakaolin has a very fine texture, and 15% of metakaolin was replaced with cement as recommended by Sahoo (2013), and its milky in colour.

vii. Fine Aggregate: sand is the product of natural and artificial disintegration of rocks and minerals. In this research work, clean sharp sand obtained from Kwangila Zaria was used in the production of the concrete cubes.

viii. Coarse Aggregate: gravel is the product of disintegration of rock, in this research work, gravel was gotten from quarry in Samaru Zaria.

ix. Water: clean tap water which is free from suspended particles, salts and oil contamination was used throughout this study.

x. Polythene: the polythene used were gotten from community market in the school premises.

xi. Polyethylene glycol: the chemical was gotten from a chemical store at Emanto and Steevemoore chemical company.

Methodology

Consistency of standard paste of the cement

A sample of 400 grams of the cement was weighed on the weighing balance, and the measured amount of cement was mix carefully with water (30% of the mass of cement). After mixing the water with the measured amount of cement carefully, a cement paste is formed. The paste was placed in the mould lying on steel plate using the gauging trowel and smoothen the top of the paste in other to place the mould under plunger in the Vicat apparatus. The plunger will penetrate from point 5 to 7 mm above the bottom of the mould [20].

Initial setting time

The initial and final setting times were determined using the Vicat apparatus in accordance with ASTM C191 (Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle). For the initial setting time, a cement paste of standard consistency was prepared, and the time water was first added (T1) was noted. A 1 mm^2 needle was gently lowered onto the paste, and the time when it penetrated to 5–7 mm above the bottom of the mould (T2) was recorded. The interval between T1 and T2 is the initial setting time, which should not be less than 45 minutes.

Final setting time

The final setting time of the cement paste was determined using the Vicat apparatus, following the procedure outlined in ASTM C191. After determining the initial setting time, the needle was replaced with a 1 mm^2 needle fitted with a metal annular collar. The needle was gently applied to the surface of the paste at 15-minute intervals. The final setting time was recorded as the time when the needle made a visible impression on the paste, but the annular collar no longer left a mark. This marks the point at which the cement paste transitions from a plastic to a hardened state.

Soundness

The Le Chatelier mould was filled with cement paste of standard consistency, and it was covered with glass plate, and immediately immersed in water for 24 hrs. The setup was then removed from the water, and measure the distance

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separating the indicator point (U1), the mould was submerged again in water and boiled for 1 hour 30 minutes. It was then removed from the boiled water and allowed to cool for some time the distance between the pointers (U2) was measured and recorded. The measure of soundness is the difference in distance between U1 and U2 [20].

Sieve analysis of aggregate

To determine the particle size distribution of fine and coarse aggregates by sieving as per BS EN 812-103.1:1985 [21].

$$\text{Weight of aggregate retained} = (\text{weight of sieve + aggregate}) - (\text{weight of sieve})\ \% \quad (1)$$

$$\text{Weight retained} = \frac{\text{Weight of aggregate retained}}{\text{Total Weight of aggregate used}} \times 100 \quad (2)$$

$$\text{Cumulative percentage passing} = 100\ \% - \text{cumulative percentage retained} \quad (3)$$

Aggregate impact value test

The aggregate impact test was carried out to evaluate the resistance to impact of aggregates in accordance with BS:812 Part 112 [22]. Aggregates passing 14.0 mm sieve and retained on 10.0 mm sieve is filled into cylindrical steel cup of internal diameter 10.2mm and depth 50mm which is attached to metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 numbers of blows. Metal hammer of weight 13.5 to 14 kg is arranged to drop with a free fall of 38.0cm by vertical guides and the test specimen is subjected 15 numbers of blows. The crushed aggregate was allowed to pass through 2.36 mm BS sieve. And the impact value is measured as percentage weight of aggregates passing the sieve (C) to the total weight of the sample (A-B).

$$\text{Aggregate impact value} = \left(\frac{C}{A-B}\right) x\ 100 \quad (4)$$

Specific gravity test

The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at specified temperature. The procedure to determine this property is described below [23].

A gas jar filled with water was weighed as P. 1kg of aggregates was weighed as B. is then poured into the cylinder and recorded as Ps.

$$\text{Weight of aggregate in air} = B \quad (5)$$

$$\text{Weight of aggregate + water + gas jar} = Ps \quad (6)$$

$$\text{Specific gravity} = \frac{B}{(P+B)-P}\ x\ S \quad (7)$$

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Slump test

Concrete's workability has never been accurately determined. Practically speaking, it usually refers to how easily a concrete mixture can be moved from the mixer to its ultimate compacted form. The property's three primary attributes are compactness, mobility, and consistency. A measure of fluidity or wetness is consistency. The ease with which a mixture can enter and fill the mould or formwork is known as mobility. The ease with which a mixture can be completely compacted to eliminate any trapped air is known as compact ability. Although there are many tests used in measuring workability such as slump test, vebe time test, flow test and compacting factor test but for the purpose this research, Slump test was used. The slump test was carried in accordance with [24,25]. It is described as follows.

A 300 mm high concrete cone was placed on a flat metal board. Fresh concrete was then placed into the cone in three successive layers and given each 35 number of blows of tamped rod. The cone was removed and a gradual deformation was observed in the moulded concrete and was measured with a steel tape.

Curing of concrete cubes

The concrete cube samples were cured by putting it in water. Samples were taken for testing at 3, 7, and 28 days. And by putting it in polythene then samples were taken for testing at 3, 7, and 28 days. And by spraying water on the concrete and samples were taken for at 3, 7, and 28 days.

Compressive strength test

The blocks were allowed to be surface dried and each of them were weighed. The two reading pointers were set to zero and the crushing machine was turned on. The blocks were placed into the crushing machine axially so that their faces touched the machine's top and bottom plates. The loading handle was turned clockwise to apply the load to the blocks. Following the blocks' failure, the imposed weight was removed, and measurements were made [26].

$$Compressive\ Strength = \frac{applied\ load\ at\ failure}{cross\text{-}sectional\ area\ of\ cube} \tag{8}$$

Result and Discussion

The result of various test conducted, which includes consistency of standard paste, initial setting time, final setting time, soundness, sieve-analysis of fine aggregate, aggregate impact value test, specific gravity test, slump test, curing of concrete and compressive strength test is presented here.

The consistency, soundness, and setting periods of cement pastes containing different pozzolanic ingredients are shown in Table 1. Water demand rose when pozzolans were added; consistency values ranged from 0.33 to 0.40, whereas OPC's was 0.31. Although significantly higher for pozzolan blends, soundness stayed within acceptable bounds. Slower hydration was indicated by

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the generally delayed initial and final setup times. With initial and final setup times of 190 and 185 minutes, respectively, LBPA and MTK demonstrated the longest setting times, indicating their potential for use in applications needing prolonged workability. Overall, the findings support the use of these materials as partial substitutes for OPC in sustainable building and demonstrate the impact of pozzolanic substitution on the characteristics of fresh cement.

Table 1. Consistency, soundness, initial setting time, and final setting time result

Pozzolana	% pozzolana in binder	Weight of cement and pozzolana	Consistency	Soundness	Initial setting time (min)	Final setting time (min)
OPC	0	400	0.31	1.0	86	161
GSA	5	380	0.33	1.0	140	234
CBA	8	368	0.35	2.3	163	260
LBPA	5	380	0.35	2.5	190	276
WOA	10	360	0.40	1.5	145	283
MTK	15	340	0.35	2.7	185	250

Table 2 shows the particle size distribution of the fine aggregate based on BS sieve analysis. The results indicate a well-graded aggregate, with the highest proportion (37%) retained on the 0.60 mm sieve. A continuous gradation is reflected in the retained mass gradually building up to 100% at the pan. Just 2.4% of the particles made it through the 0.15 mm filter, compared to almost 67% that made it through the 1.18 mm sieve. In order to produce workable concrete with fewer voids and better packing density, thereby increasing strength and durability. This distribution indicates a desirable mix of fine and coarse particles.

Table 2. Result for particle gradation for fine aggregate

BS Sieve Sizes (mm)	Weight Retained (g)	% Mass Retained	Cumulative %	Mass %
4.76	16	3.2	3.2	96.8
2.36	32	6.5	69.7	90.3
1.18	115	23.3	33.0	67.0
0.60	183	37.0	70.0	30.0
0.30	111	22.5	92.5	7.5
0.15	25	5.1	97.6	2.4
Pan	12	2.4	100	0.0

Figure 1 presents the graph of percentage passing (%) versus sieve sizes (mm) for fine aggregate. The graph illustrates a well-graded particle distribution, which is essential for producing workable and durable concrete. According to EN 196-6, fine aggregates used in construction should have particle sizes smaller than 5 mm. The analysis shows that approximately 97% of the sample passes through the 4.76 mm sieve, indicating its suitability for use as fine aggregate in concrete applications.

Table 3 presents the particle size distribution of the coarse aggregate using BS sieve analysis. According to the results, the aggregate is well-graded, with the

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majority of the particles remaining between the 19.05 mm and 25.40 mm sieves, accounting for 76.8% of the total. The 19.05 mm sieve had the largest mass retained (53.4%), suggesting that medium-sized particles predominated. On the 6.35 mm sieve, only 2.2% of the material was retained, and on the 38 mm sieve, none at all. According to the distribution, the coarse aggregate is appropriate for use in the manufacturing of concrete because it provides acceptable strength development in the hardened concrete mix, good packing, and fewer voids.

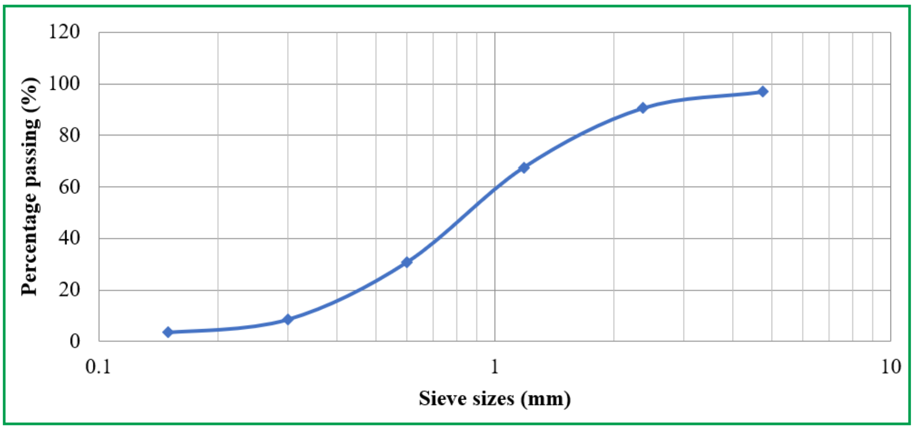

Figure 1. Graph of percentage passing (%) against sieve sizes in mm for fine aggregate

Table 3. Result for particle size distribution for coarse aggregate

BS Sieve Sizes (mm)	Weight Retained (g)	% Mass Retained	Cumulative %	Mass %
38.00	0.00	0.00	0.00	100.00
25.40	1.17	23.40	23.40	76.60
19.05	2.67	53.40	76.80	23.20
12.70	0.52	10.20	87.00	13.00
9.52	0.36	7.20	94.20	5.80
6.35	0.18	3.60	97.80	2.20
4.75	1.10	2.20	100.00	0.00

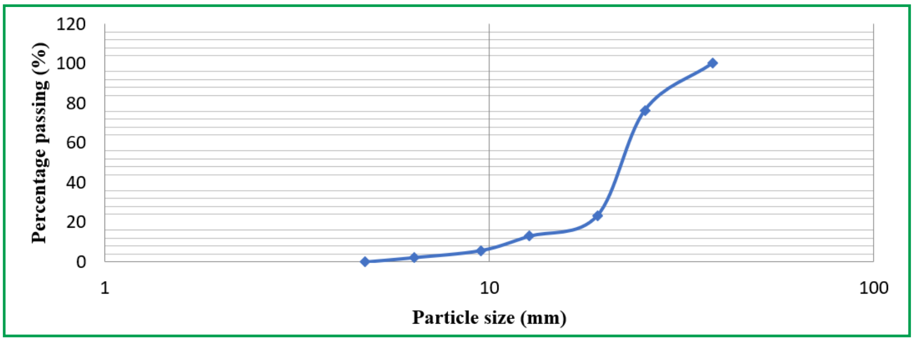

Figure 2. Particle size distribution of coarse aggregate

According to BS EN 196-6, coarse aggregate particles suitable for construction should be less than 40 mm in size. Figure 2 illustrates the percentage of material passing through each sieve size, confirming the particle size distribution of

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the coarse aggregate sample. This gradation ensures the material meets the standard requirements for use in concrete construction.

Aggregate Impact Value (AIV)

This test measures the resistance of aggregate to sudden shock or impact, which is essential for understanding its durability under dynamic loads. A lower AIV indicates better performance of the aggregate, contributing to the overall strength and stability of the concrete.

Total mass of sample (A) = 500 g

Mass of residual sample (B) = 150.25 g

Mass of sample passing sieve 2.36mm after crushing (C) = 66 g

AIV = C/(A-B) x 100

AIV = 66/(500-150.25) ×100 = 18.87 %

BS 812, Part 112 (1990), specifies a value of AIV for coarse aggregate between 0-30 percent as excellent for important engineering work. The result shows that the aggregates have good resistance for sudden shock or impact, since they fall below the maximum impact value of the 45 %.

Results on Specific Gravity Test for Fine and Coarse Aggregates

Specific gravity of aggregates is measured to assess the density and quality of the materials used. This property can affect both the weight and strength of the final concrete mix, with higher values generally indicating more durable aggregates.

Specific gravity of fine aggregate

Mass of fine aggregate + pycnometer (B) = 0.50 kg

Mass of water + pycnometer (P) = 1.58 kg

Mass of fine aggregate + water + pycnometer (Ps) = 1.89 kg

Specific gravity = B/(P+B-Ps)

Specific gravity = 0.50/(0.50+1.58-1.89) = 2.63

ASTM D854-14 states that the specific gravity of aggregates should be between 2.6 and 2.9. The specific gravity is of interest because it is used in the mix design of concrete.

Specific gravity of coarse aggregate

Mass of coarse aggregate + pycnometer (B) = 1.00 kg

Mass of water + pycnometer (P) = 2.07 kg

Mass of coarse aggregate + water + pycnometer (Ps) = 2.70 kg

Specific gravity = B/(P+B-Ps)

Specific gravity = 1.00/(1.00+2.07-2.70) = 2.70

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ASTM D854-14 states that the specific gravity of aggregates should be between 2.6 to 2.9. The specific gravity is of interest because it is used in the mix design of concrete.

Slump Test

Conducted to assess the workability of fresh concrete, the slump test provides an indication of its flow characteristics. This property is essential for ensuring the concrete can be adequately mixed, transported, and placed, particularly in pozzolanic concrete, where workability may vary depending on the mix proportions.

Table 4. Slump test value for various pozzolanic concrete

Pozzolana in Concrete	Slump Value (mm)
Groundnut Shell Ash	25
Locust Beans Pod Ash	21
Coal Bottom Ash	27
Metakaolin	24
Wood Ash	22

Table 4 compares the slump results of the concrete with different type of pozzolana which includes groundnut shell ash, locust beans pod ash, coal bottom ash, metakaolin and wood ash, which shows that the slump for groundnut shell is 25mm, and for locust beans pod ash is 21, coal bottom ash is 27, metakaolin is 24, wood ash is 22.

Compressive Strength Test Result

The compressive strength test is essential for assessing the load-bearing capacity of concrete, as it determines the maximum stress the material can withstand before failure. This test provides critical insight into the structural performance of concrete, especially in load-resisting applications. Figures 3 to 7 present the compressive strength values of pozzolanic concrete incorporating various pozzolanas: groundnut shell ash (GSA), coal bottom ash (CBA), locust bean pod ash (LBPA), metakaolin, and wood ash. The concrete samples were subjected to different curing methods—polyethylene glycol (PEG), ponding, impermeable covering, and spraying—over curing durations of 1, 3, 7, 14, and 27 days. These figures collectively illustrate the influence of both pozzolanic material type and curing method on the development of compressive strength over time.

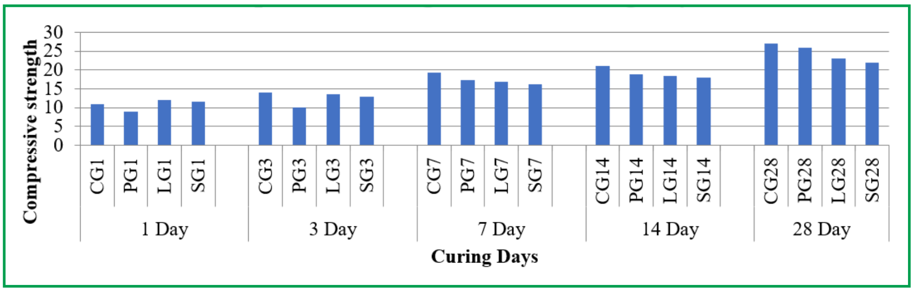

Figure 3. Compressive strength with GSA using different curing method

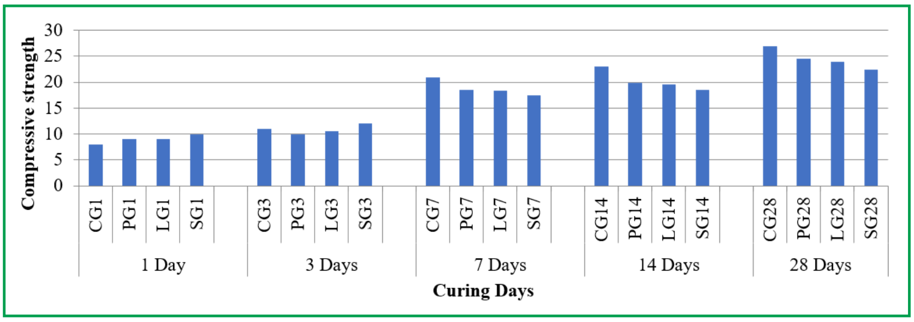

Figure 4. Compressive strength concrete with CBA using different curing method

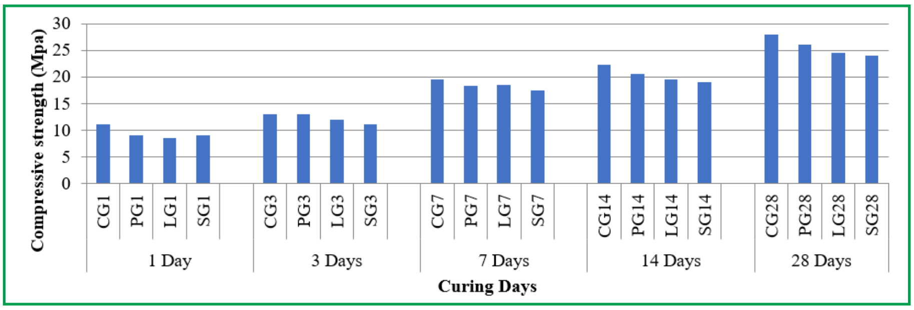

Figure 5. Compressive strength of concrete with LBPA using different curing method

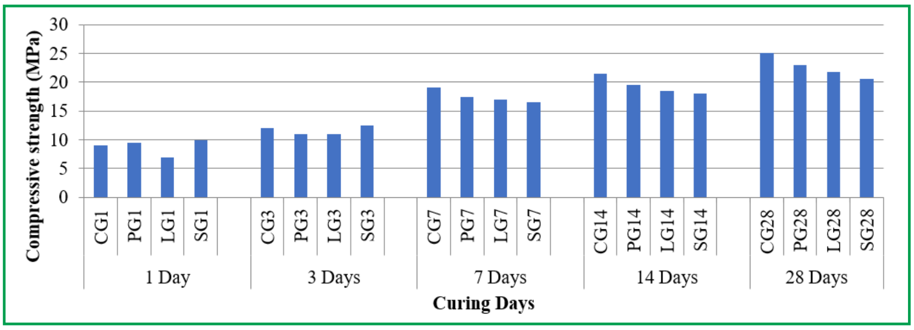

Figure 6. Compressive strength for metakaolin concrete using different curing method

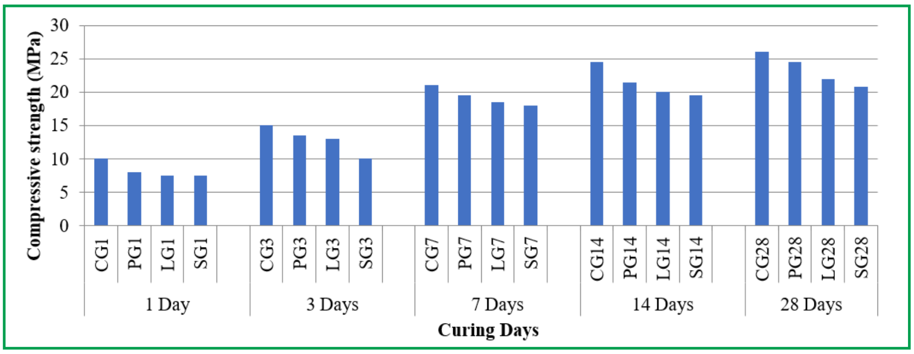

Figure 7. Compressive strength for wood ash concrete using different curing method

Based on the compressive strength results, the study confirms that pozzolanic concrete experiences continuous strength development with extended curing duration, highlighting the importance of adequate curing time to achieve optimal strength. All concrete mixtures exhibited a progressive increase in strength,

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with the most notable gains occurring within the first 28 days. Among the tested mixes, the polymer-modified group (PG) demonstrated the highest performance, reaching 42.1 MPa at 28 days and further increasing to 55.0 MPa by 249 days. This sustained strength gain indicates ongoing pozzolanic activity beyond the initial curing period. In comparison, the control group (CG) showed slower strength development, achieving 35.0 MPa at 28 days and 50.2 MPa at 249 days. These differences in strength progression suggest that the type of curing method and additive used has a significant impact on the hydration process and long-term strength performance of pozzolanic concrete.

Curing methods significantly influenced the strength development of pozzolanic concrete. Among the techniques evaluated, chemical curing with polyethylene glycol (PEG) proved to be the most effective, followed by ponding, moist covering, and non-porous covering. This performance hierarchy highlights the superiority of active curing methods in promoting optimal strength gain, as they better maintain moisture for continued hydration. The results emphasize the importance of selecting suitable curing techniques and durations, especially in pozzolanic concrete where hydration rates may vary. While strength development continues beyond 28 days, the early curing phase is critical for ensuring adequate performance in structural applications. Chemical curing is particularly advantageous for high-performance mixtures requiring enhanced durability and strength, whereas conventional methods like ponding or moist covering may be sufficient for standard construction needs. These findings underline the need to align curing practices with the intended concrete application to achieve desired structural outcomes.

The compressive strength results revealed notable variations among the different pozzolanic concrete samples, largely influenced by the curing methods applied. While all curing techniques contributed to strength improvement, their effectiveness varied. Chemical curing using polyethylene glycol (PEG) produced the highest strength values, followed by ponding with cover, covering alone, and lastly, non-porous covering. This trend highlights that the selection of an appropriate curing method plays a critical role in optimizing the performance of pozzolanic concrete. Effective curing ensures adequate moisture retention, supporting continued hydration and strength development. Therefore, tailoring the curing approach to the specific pozzolanic mix is essential for achieving desired structural performance.

CONCLUSIONS

This study evaluated the effects of different curing techniques on the performance of pozzolanic concrete, with a focus on strength development and workability. The key findings demonstrate that curing methods significantly influence concrete properties, with chemical self-curing proving most effective in enhancing compressive strength, followed by ponding, impermeable covering, and spraying. The results confirm that prolonged curing duration is essential for optimal strength gain in pozzolanic concrete. Additionally, the workability of concrete varied with pozzolanic substitutions, where coal bottom ash exhibited the highest workability and locust bean pod ash the lowest. Despite these variations, all blended mixtures met standard consistency and setting time requirements, validating their suitability for practical applications. These findings highlight the importance of selecting appropriate curing techniques to maximize the performance of pozzolanic concrete. The study provides valuable insights for optimizing curing protocols in both research and construction practices, ensuring improved durability and strength outcomes.

Recommendation

Based on the findings of this study, the most effective curing method for pozzolanic concrete is the use of self-curing chemicals, particularly polyethylene glycol (PEG), followed by ponding, and then impermeable covering. Among the methods tested, spraying proved to be the least effective, resulting in the lowest compressive strength at 28 days. These outcomes highlight the importance of selecting appropriate curing techniques to ensure optimal strength development. To further enhance the performance and durability of pozzolanic concrete, future research should focus on cost-benefit analyses of various curing methods and investigate the microstructural changes that occur during hydration. Such studies will provide deeper insight into optimizing mix designs and curing protocols for improved long-term performance. Additionally, subsequent investigations should explore the influence of different curing techniques on other mechanical properties of pozzolanic concrete, such as tensile and flexural strength, as well as its resistance to adverse environmental conditions. Assessing the long-term durability and economic feasibility of pozzolanic materials and curing compounds in large-scale applications will also be crucial for their practical implementation in the construction industry.

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Conflicts of Interest

The authors declare that they have no competing interests.

Author Contributions

Yaseer Adam Nabage: writing-original draft, conceptualization, methodology. **Aliyu Mani Umar:** investigation, data curation, writing-reviewing and editing. **Bala Ismail Muhammad:** supervision, validation. **Abdulkareem Abdulrahman:** resources, validation.

Data Availability Statement

The data used to support the findings of this study are included within the article.

References

[1] ASTM C33/C33M-18, Standard Specification for Concrete Aggregates. West Conshohocken, PA: ASTM International, 2018.

[2] A. A. Raheem, A. A. Soyingbe, and A. J. Emenike, "Effect of curing methods on density and compressive strength of concrete," Int. J. Appl. Sci. Technol., vol. 3, no. 4, pp. 55–64, 2013.

[3] H. A. Toutanji and Z. Bayasi, "Effect of curing procedures on properties of silica fume concrete," Cem. Concr. Res., vol. 29, pp. 497–501, 1999, doi: http://dx.doi.org/10.1016/S0008-8846(98)00197-5.

[4] A. M. Neville, Properties of Concrete, 5th ed. London, U.K.: Pearson, 2010.

[5] J. de-Prado-Gil et al., "A study on the prediction of compressive strength of self-compacting recycled aggregate concrete utilizing novel computational approaches," Materials, vol. 15, no. 15, p. 5232, 2022, doi: http://dx.doi.org/10.3390/ma15155232.

[6] O. Zaid et al., "To determine the performance of metakaolin-based fiber-reinforced geopolymer concrete with recycled aggregates," Arch. Civ. Mech. Eng., vol. 22, no. 3, p. 114, 2022, doi: http://dx.doi.org/10.1007/s43452-022-00430-8.

[7] M. K. D. Rout et al., "Feasibility study of reclaimed asphalt pavements (RAP) as recycled aggregates used in rigid pavement construction," Materials, vol. 16, no. 4, p. 1504, 2023, doi: http://dx.doi.org/10.3390/ma16041504.

[8] B. H. Z. Sami et al., "Feasibility analysis for predicting the compressive and tensile strength of concrete using machine learning algorithms," Case Stud. Constr. Mater., vol. 18, p. e01893, 2023, doi: http://dx.doi.org/10.1016/j.cscm.2023.e01893.

[9] BS 12:1996, Specification for Portland Cement. London, U.K.: British Standards Institution, 1996.

[10] ASTM C618-78, Standard Specification for Pozzolanas. West Conshohocken, PA: ASTM International, 1978.

[11] D. Meng et al., "Carbon sequestration and utilization in cement-based materials and potential impacts on durability of structural concrete," Constr. Build. Mater., vol. 361, p. 129610, 2022, doi: http://dx.doi.org/10.1016/j.conbuildmat.2022.129610.

[12] K. H. Khayat et al., "Rheological properties of ultra-high-performance concrete—An overview," Cem. Concr. Res., vol. 124, p. 105828, 2019, doi: http://dx.doi.org/10.1016/j.cemconres.2019.105828.

[13] P. Sikora et al., "Evaluating the effects of nanosilica on the material properties of lightweight and ultra-lightweight concrete using image-based approaches," Constr. Build. Mater., vol. 264, p. 120241, 2020, doi: http://dx.doi.org/10.1016/j.conbuildmat.2020.120241.

[14] R. Remya, P. Mattew, and K. Aboobacker, "Strength of concrete containing coal bottom ash," Int. J. Res. Eng. Technol., vol. 3, no. 4, pp. 1–6, 2014.

[15] C. Argiz, M. Á. Sanjuán, and E. Menéndez, "Coal bottom ash for Portland cement production," Adv. Mater. Sci. Eng., vol. 2017, Art. no. 6068286, 2017, doi: http://dx.doi.org/10.1155/2017/6068286.

[16] A. Y. Adama and Y. A. Jimoh, "Production and classification of locust bean pod ash (LBPA) as a pozzolan," Civ. Eng. Portal, 2011. . Available: http://www.engineeringcivil.com/production-and-classification-of-locust-bean-pod-ash-lbpa-as-a-pozzolan.html.

[17] E. A. Basha, R. Hashim, and A. S. Muntohar, "Effect of the cement-rice husk ash on the plasticity and compaction of soil," Electron. J. Geotech. Eng., vol. 8, no. 1, pp. 1–10, 2003. Available: http://www.ejge.com/2003/Ppr0304/Ppr0304.zip.

[18] A. S. Batt and A. Garg, "Partial replacement of wood ash with ordinary Portland cement and foundry sand as fine aggregate," J. Civ. Environ. Eng., vol. 7, no. 3, pp. 1–8, 2017.

[19] T. Bhavan, K. Madhu, and E. Syed, "Study on partial replacement of cement with metakaolin," Int. J. Adv. Res. Innov., vol. 4, no. 2, pp. 45–52, 2016, doi: http://dx.doi.org/10.21474/IJAROI/2394.

[20] BS EN 196-3:1995, Methods of Testing Cement—Part 3: Determination of Setting Time and Soundness. London, U.K.: British Standards Institution, 1995.

[21] BS 812-103:1985, Testing Aggregates—Method for Determination of Particle Size Distribution. London, U.K.: British Standards Institution, 1985.

[22] BS 812-112:1990, Testing Aggregates—Method for Determination of Aggregate Impact Value (AIV). London, U.K.: British Standards Institution, 1990.

[23] ASTM C136-78, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. West Conshohocken, PA: ASTM International, 1978.

[24] BS 1881-102:1983, Testing Concrete—Method for Determination of Slump. London, U.K.: British Standards Institution, 1983.

[25] BS EN 12350-2:2009, Testing Fresh Concrete—Part 2: Slump Test. London, U.K.: British Standards Institution, 2009.

[26] BS 1881-116:1983, Testing Concrete—Method for Determination of Compressive Strength of Concrete Cubes. London, U.K.: British Standards Institution, 1983.

https://doi.org/10.70028/sgm.v2i2.43