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RESEARCH ARTICLE OPEN ACCESS

EVALUATION OF THE MECHANICAL PROPERTIES OF CONCRETE MIXED WITH WATER-SOLUBLE POLYMER

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ABSTRACT

Polyvinyl alcohol (PVA) is a water-soluble polymer whose impact on concrete properties requires further investigation. Thus, this study established the appropriate dose and applicability of PVA to produce the foremost improvement in the mechanical characteristics of concrete. The study produced 40 concrete cubes and 12 cylinders of concrete specimens at 0%, 0.5%, 1%, 1.5%, and 2% doses of PVA. A number of tests were carried out on the specimens to ascertain their performances. The results showed that a 0.5% addition of PVA to the concrete mixture yields an optimal compressive strength of 24.98N/mm^2 after 28 days, while the tensile strength increased as the percentage of PVA increased. Besides, the bond strength of the PVA-modified concrete decreased as the proportion of PVA in the concrete mixture increased. The study concludes that a 0.5% addition of PVA to concrete is the ideal dose for enhanced compressive strength. Also, the study concludes that, while the tensile strength of concrete increases with increasing PVA doses, the bond strength of concrete and rebars decreases as the percentage of PVA increases. This implies that PVA is unsuitable for reinforced concrete structural works. The study therefore recommends that PVA should be applied for non-structural reinforced concrete works.

I. INTRODUCTION

Concrete is one of the most often utilized building materials and is regarded as a composite material made of cement, water, and aggregates [1], [2]. The properties of hardened concrete include its strength, durability, and dimensional stability. [3] substantiate that these properties of concrete may be enhanced through the introduction of different chemical admixtures, such as plasticizers, superplasticizers, and polymers. [4] posit that a category of admixtures called polymers are commonly employed in products like cement binders and notable examples include recognized additions of latexes, organosilicon compounds, polyvinyl acetate, polyvinyl alcohol (PVA), and other polymer cement compositions.

PVA has been demonstrated to increase concrete's mechanical properties and durability by boosting its compressive strength, tensile, and flexural strength [5]. Previous studies have shown that PVA has the ability to considerably improve the characteristics of concrete, making it an important addition to the manufacturing process [5, 6, 7]. In this regard, [8] found that adding PVA as a bonding admixture to concrete can boost its compressive strength. The authors note that a 0.3% addition of PVA by the unit weight of cement was the ideal mix ratio for maximizing compressive strength enhancement. Similarly, [9] found that PVA can improve the compressive strength of concrete by up to 26% at a dosage of 1% PVA by weight of cement. Besides, [10] opine that the addition of PVA fibre to concrete greatly enhanced its tensile strength while only somewhat improving its compressive strength. While noting that the higher the amount of fibre inclusion, the greater the potential of pore connections in the matrix, resulting in a drop in the tensile strength of concrete. Meanwhile, [11] conducted studies on self-curing concrete of M30 grade by using PVA.

It was discovered that 2% PVA gives lower compressive strength and split tensile strength in comparison to water-cured specimens without self-curing agents. Consequently, it has been revealed that the addition of PVA at large doses over 1.5% of cement does not provide the predicted results in strength and cannot be employed realistically. [12] investigated the use of recycled concrete aggregate with PVA, and the results revealed the maximum inclusion (2%) resulted in a 52% improvement in strength over the reference concrete with 0% incorporation. While PVA has been extensively applied to building and infrastructural projects on the global stage, there are fewer studies on the African continent on the application of PVA in concrete on these monumental projects. The Egyptian study by [13] examined the behavior of Reinforced Concrete Columns with PVA Under Fire. In addition, the Egyptian study by [14] evaluated the enhancement of tensile strength of high strength Concrete using PVA Fibre. Yet, in the context of Nigeria, very limited studies are currently available on the technical know-how and competence regarding the proper application of PVA in the Nigerian concrete industry.

This has created a gap in the need for literature on the applications of PVA as an admixture for concrete works in Nigeria. Also, the majority of literature on PVA used concrete manufactured with cement and aggregates in the country where these studies were undertaken [14-17]. Hence, studies on PVA utilizing Nigerian concrete materials are required since the characteristics of various materials vary depending on their geographical origin**.**

Considering the foregoing, this study establishes the appropriate dose and applicability of PVA to produce the foremost improvement in the mechanical characteristics of concrete. The objectives of this study are to evaluate the impacts of PVA addition to concrete mixtures, identify the mechanical characteristics of the resulting concrete, and find the appropriate PVA dose for concrete manufacturing. The study is significant because it increases concrete workability, lowers permeability, reduces cracking and improves cement-aggregate adhesion, resulting in a more resilient and flexible concrete structure.

II. THEORETICAL REFERENCE

II.1 DEFINITION AND MECHANICAL CHARACTERISTICS OF CONCRETE

Concrete is defined as a highly complex heterogeneous material whose response to stress is determined not only by the response of the individual components but also by the interaction between those components. The components of concrete are binder (cement), aggregates (fine and coarse), and water. According to [2], concrete is one of the most widely utilized products in the building and construction sector. Oftentimes, admixtures are added to the concrete mixture immediately before or during mixing to enhance concrete properties for diverse desired effects. On such admixture is PVA, which according to [4], has been classified as a polymeric additive that enhances the mechanical properties of concrete.

The mechanical qualities of concrete, such as its tensile, flexural, and compressive strengths, define a structure's ability to support loads and maintain its overall structural integrity. Accordingly, a prerequisite for how the concrete may be loaded is that it is able to create the appropriate mechanical strength [18]. The addition of polymers to concrete can drastically alter its mechanical properties [14], [19]. It has high adherence to the concrete substrate, high tensile and flexural strength, and low shrinkage and permeability [20]. PVA is typically added to the concrete mix during the mixing process, along with the other dry ingredients [21].

II.2 BIBLIOMETRIC EVALUATION OF PVA CONCRETE

The Scopus and VOSviewer programme was used to perform a bibliometric evaluation, with the terms "PVA" and "Concrete" on dimensionAI and "PVA" or "Polyvinyl Alcohol" and "Concrete" on Scopus to search for relevant publications. The review's aim was to assess the present status of research on the use of PVA in concrete manufacture. The findings of this research are visually shown in Figures 1 through 6. Based on co-author and citation patterns, the Scopus and VOSviewer programme were used to trace the links between the papers discovered.

According to the findings of the investigation, the most often referenced publications on the subject originated in China, the United States and Canada, India and Malaysia, Australia, Japan and South Korea, the United Kingdom and Germany. While each of these countries represented a separate continent, it was discovered that there were few publications from Africa.

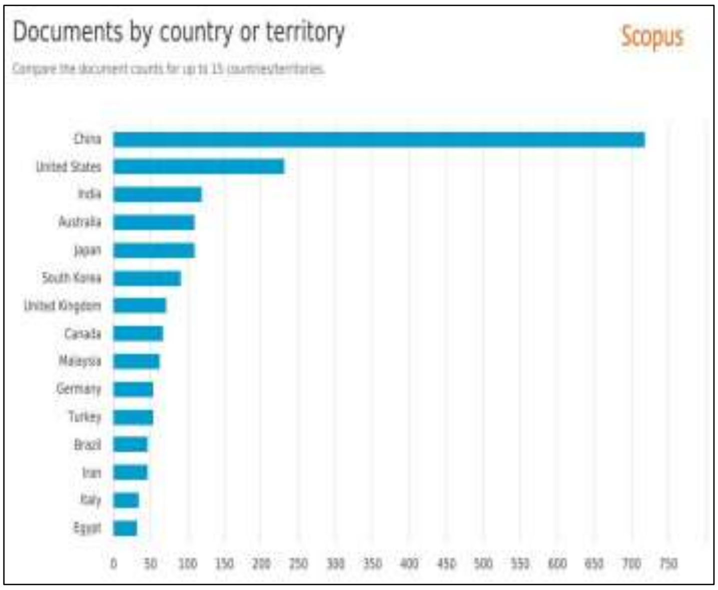

Figure 1: Scopus Analysis.
Source: Authors, (2025).

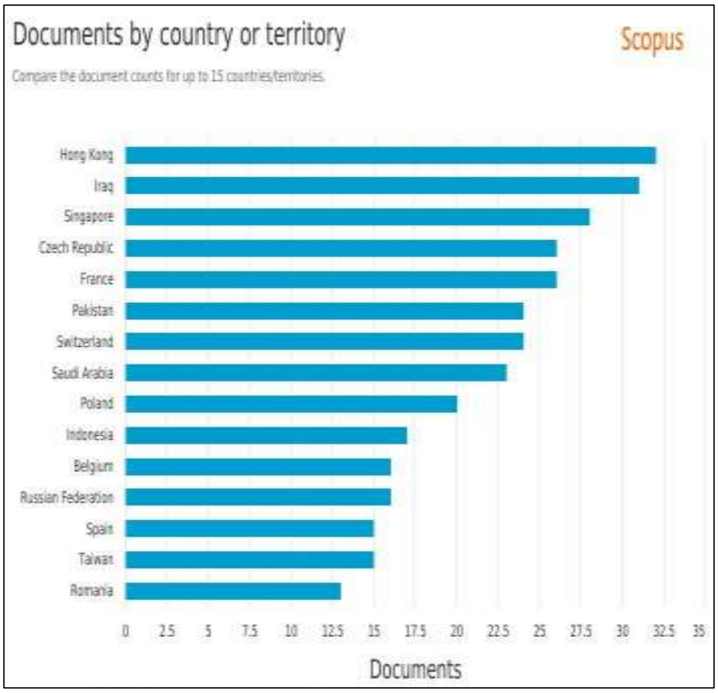

Figure 2: Scopus Analysis
Source: Authors, (2025).

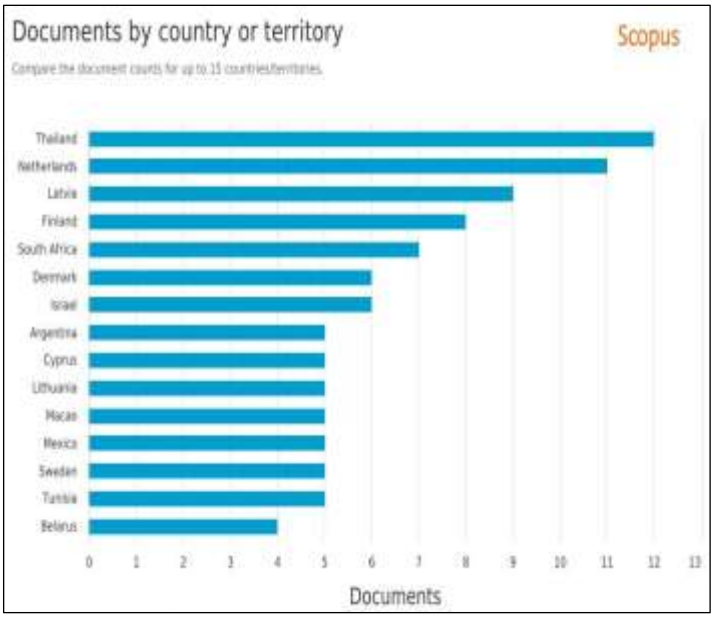

Figure 3: Scopus Analysis.
Source: Authors, (2025).

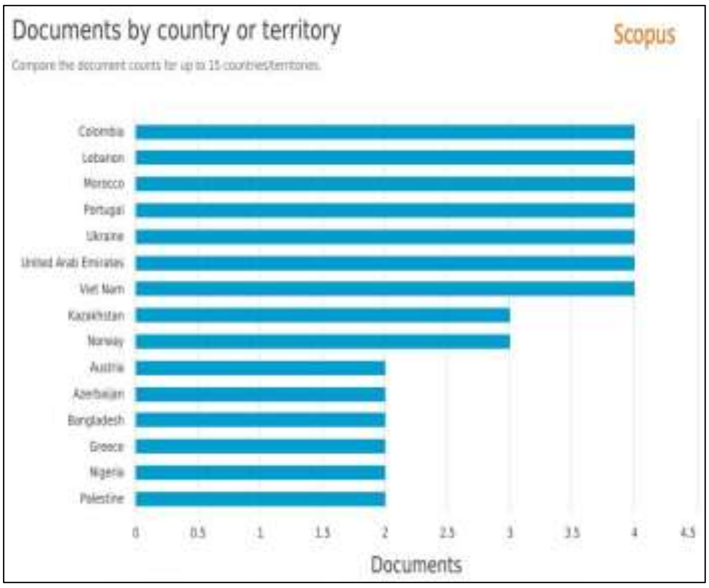

Figure 4: Scopus Analysis.
Source: Authors, (2025).

According to the Scopus data, Nigeria has just two articles out of a total of 4240 papers matching the keywords. According to the findings of the bibliometric evaluation, there is a substantial amount of research being undertaken on the subject of employing PVA in concrete manufacturing, with the bulk of the studies coming from Asia, North America, and Europe. Yet, it was discovered that there is minimal study in this sector in Africa. This might imply a knowledge and awareness gap in the region about the potential benefits of PVA in concrete manufacturing.

This absence of research in Africa might have serious consequences for the continent's construction industry. As a result, investigations on PVA employing African concrete materials are required. Despite the potential benefits of PVA, few researches have been conducted on the technical knowledge and experience required for the right usage and use of PVA in concrete production. As a result, further study is required to improve experimental procedures, strengthen a systematic approach, and enhance specialized understanding.

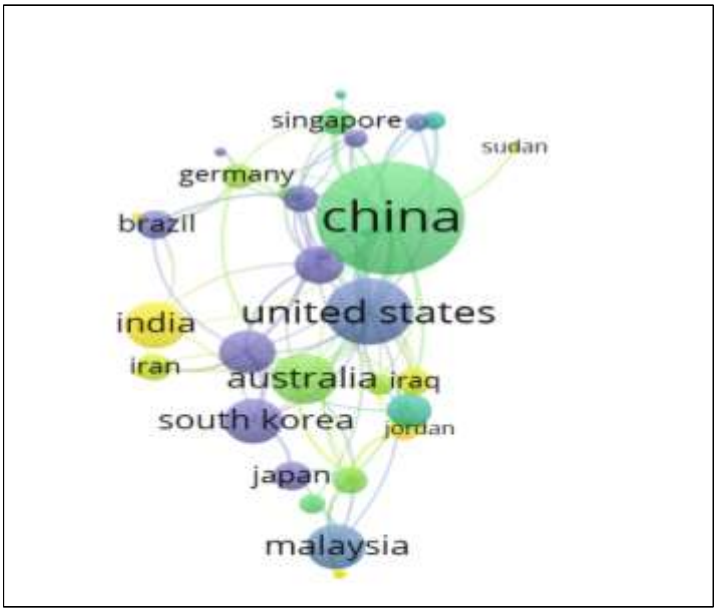

Figure 5: VOSviewer graphical representation of authors of PVA works of literature by country of origin.
Source: Authors, (2025).

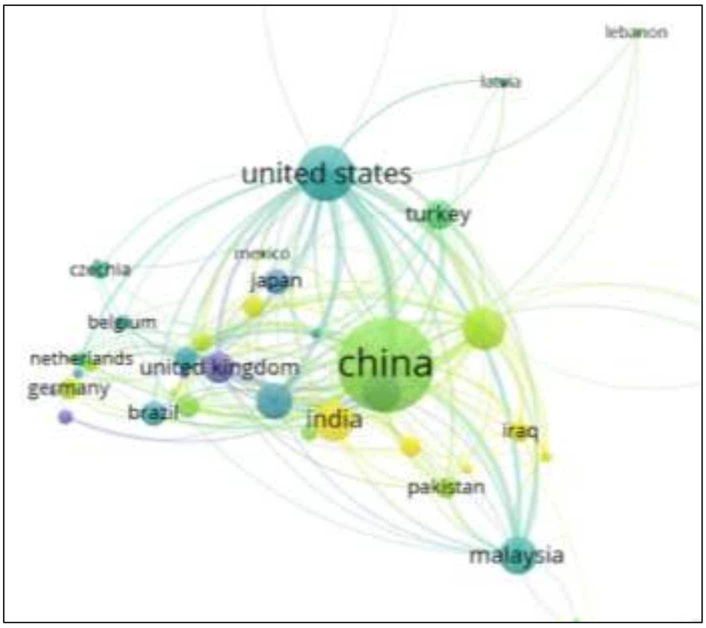

Figure 6: VOSviewer graphical representation of citations of PVA works of literature by country of origin
Source: Authors, (2025).

II.3 EFFECTS OF PVA ON THE MECHANICAL PROPERTIES OF CONCRETE

11.3.1 COMPRESSIVE STRENGTH OF PVA ENHANCED CONCRETE

According to [22], compressive strength is the capacity of concrete to support compressive loads. It is often determined by applying a load on cylindrical concrete specimens until failure [23]. The type and quantity of cement, the water-to-cement ratio, the aggregate size and type, and the curing conditions all have an impact on the compressive strength of concrete [24]. Besides, temperature has an impact on the compressive strength of concrete as well. Concrete has a stronger compressive strength at low temperatures than it does at normal temperatures [25].

The impact of PVA on the compressive strength of concrete has been the subject of several investigations. PVA may be added to concrete as a boding additive to increase its compressive strength. [26] assessed the addition of polyvinyl acetate to increase the strength of porous concrete for a mix ratio of 1:2:4 with a 0.4% water-to-cement ratio. Concrete was produced with 0%, 0.25%, 0.5%, 0.75%, and 1% addition of PVA in order to compare the strength. The results indicate that concrete produced using 0.75 addition of polyvinyl acetate gave the maximum strength at 28 days with 11.46 N/mm^2 with the control sample producing 8.36 N/mm^2 at 28 days.

In the same vein, [27] carried out a similar experiment using a concrete ratio of 1:2:4 at 0.4% water cement ratio with a 0%, 0.25%, 0.5%, 0.75%, and 1% addition of PVA. The results revealed that the compressive strength of concrete increases, with an increasing percentage of PVA proportion. The 1% addition of PVA produced the highest compressive strength of 13.78 N/mm^2 at 28 days. [28] discovered that a 0.3% addition of PVA fibre to a concrete mixture gave the optimum results after 28 days. According to [29], the addition of fibre typically results in a 16% increase in compressive strength at 28 days with an optimal fibre volume fraction of 0.25%.

Meanwhile, [30] averred that a 0.4% of addition of PVA to concrete is the optimal amount required to enhance the properties of concrete. This present study notes that the ideal proportions of PVA in concrete might differ depending on the environment, the properties of the material, and the testing setup. Diverse environmental and contextual factors may be taken into account by different authors and research, resulting in variances in the suggested PVA dose for concrete to achieve maximum performance in different locations and situations. This study therefore attempts to establish a universal mixing and testing protocol to maximum dosage that will enhance the compressive strength and improve concrete performance.

11.3.2 TENSILE STRENGTH OF PVA ENHANCED CONCRETE

One essential characteristic of concrete that is critical to evaluating its mechanical performance is its tensile strength [31]. It is the fundamental characteristic used to analyse concrete fracture processes and estimate the structure's resistance to cracking [32]. The capacity of concrete to bear tension is known as tensile strength, and it is commonly assessed using a split tensile test, which involves applying a weight to a cylindrical specimen [31]. The splitting technique is mostly used to assess the tensile strength of concrete since direct tensile tests need an eccentric specimen installation and because the specimen's geometric axis and physical centre of gravity may vary [25].

Similar to compressive strength, tensile strength in concrete is often lower and influenced by the same elements [33]. With an increase in the maximum temperature, several of the parameters influencing the tensile strength dramatically decrease [34]. According to research by [35] on the impact of PVA on the mechanical properties of geopolymer concrete based on fly ash, a volume fraction of 0.8% was suggested in order to obtain good toughness and tensile qualities while preserving the compressive performance of the concrete. [12] investigated the use of recycled concrete aggregate with PVA, and the results show that the maximum inclusion of 2% PVA resulted in a 52% improvement in the tensile strength of the concrete produced over the reference concrete with 0% incorporation.

11.3.3 BOND STRENGTH OF PVA-ENHANCED CONCRETE

It has been discovered that PVA has a greater impact at younger ages when cement hydration has not yet fully contributed to the binding [36]. According to [30], bond resistance may be decreased by using PVA fibre in levels higher than 0.6% with the study's specimen exhibiting a 0.8% concentration of PVA fibre demonstrating the situation. As the amount of PVA fibre in fresh concrete increases, its workability decreases. Meanwhile, [37] affirmed that the quantity of PVA used impacts the bond strength of concrete. Insisting that the bond strength of concrete increases as the percentage of addition of PVA increases.

III. MATERIALS AND METHODS

III.1 MATERIALS

The materials used in the study were ordinary Portland cement (OPC), fine aggregate (Sharp sand), coarse aggregate (Granite), PVA, and water.

III.1.1 Ordinary Portland Cement

The cement used in the experimental study was "Elephant Supaset" Cement which is a Portland Limestone Cement, conforming to the Nigerian Industrial Standards NIS 444-1: 2003 & EN 197-1:2011 specifications for Cement. The cement is produced by Lafarge Africa Plc. This cement is of grade 42.5. It is available in specially designed 50 kg bags. It is displayed in Figure 7.

Figure 7: Elephant Supaset cement packaging
Source: Authors, (2025).

III.1.2 FINE AGGREGATE

The fine aggregate used in the experimental study was river sand obtained through a local supplier from the Ogun River Basin. The sand was screened to remove any impurities and particles using sieve no. 230 and conforms to the requirements of BS EN 12620 for sand and test sieve with a mesh size of 63 microns (um). The sharp sand used contains no substances that are liable to lead to unsoundness or react in a harmful way with the concrete produced. It is displayed in Figure 8.

Figure 8: Sieving of fine aggregate (sand).
Source: Authors, (2025).

III.1.3 COARSE AGGREGATE

The coarse aggregate used in the experimental study was crushed Granite obtained from local quarry sites in Ogun state, Nigeria. Although the coarse aggregates come in different sizes, aggregate sizes ranging from 12-19mm were used for the study. It is shown in Figure 9.

Figure 9: Coarse aggregate (Granite)
Source: Authors, (2025).

III.1.4 PVA POWDER

The polyvinyl alcohol (PVA) powder used in the experimental study was procured from a local chemical market at Ojota, Lagos state. PVA is the compound of Polyethylene Glycol. It is a water-soluble synthetic polymer. It is represented in Figure 3.4. PVA is an odourless and tasteless, translucent, white colour in Crystal form with a density ranging from 1.17-1.3g/cm^3. The properties of the PVA powder used are further displayed in Table 10.

Figure 10: PVA Additive
Source: Authors, (2025).

Table 1: Properties of PVA powder.

PVA Properties	Colour	State	Density (g/cm^3)	Tensile strength	Chemical Symbol
	White	Solid (granules)	1.17-1.3	1500Mpa	$(C_4H_6O_2)_x$

Source: Authors, (2025).

III.1.5 WATER

The water used in the experimental study was clean and potable. It was removed unsoiled and devoid of harmful levels of oils, acids, alkalis, salts, sugar, organic material, and other things that might harm concrete. Water is a necessary component in the making of concrete and is important for the hydration of cement.

III.2 METHODS

The preparation of samples and tests was carried out at the Department of Building and Civil and Engineering department at the University of Lagos Concrete Laboratory.

III.2.1 MIX DESIGN

The mix design for the experimental study was based on the BS 1881 standard for making and curing concrete test specimens in the laboratory. The mix proportions for the control mix and the PVA-modified mixes are presented in Tables 2 and 3. Table 2 shows the mix proportion used to prepare the specimens for compressive and pull-out tests. The mix was obtained by multiplying the volume of the concrete specimen by the density of the concrete. Waste and shrinkage were factors in the calculation. The total number of cubes per mix reference is 8. That is 4 cubes for compressive test strength and 4 cubes per mix reference for the pull-out test. Resulting in a total of 20 cubes for each compressive and pull-out test respectively.

Table 3 shows the mix proportions for the cylindrical specimen. The total number of cylindrical specimens per mix reference is 4. That is, 4 cylindrical specimens per mix reference resulting in a total of 12 cylindrical specimens for the split tensile test.

Table 2: Mix proportion for cubical specimens.

Mix Ref	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (kg)	PVA (kg)	w/c Ratio
CP0	12.22	24.44	48.88	8	0	0.66
CP.5	12.22	24.44	48.88	8	0.061	0.66
CP1	12.22	24.44	48.88	8	0.12	0.66
CP1.5	12.22	24.44	48.88	8	0.18	0.66
CP2	12.22	24.44	48.88	8	0.24	0.66

Source: Authors, (2025).

Table 3: Mix proportion for cylindrical specimens.

Mix Ref	Cement (kg)	Fine Aggregate(kg)	Coarse Aggregate(kg)	Water (kg)	PVA (kg)	w/c Ratio
T0	10.178	20.356	40.712	6.62	0	0.65
T1	10.178	20.356	40.712	6.62	0.10	0.65
T2	10.178	20.356	40.712	6.62	0.20	0.65

Source: Authors, (2025).

III.2.2 MIXING AND PRODUCTION OF SPECIMENS

Prior to mixing, the cubical and cylindrical moulds were thoroughly cleaned and oiled to allow for simple de-moulding once the concrete had set before curing commences. The materials were also batched by weight prior to mixing. The concrete mixes were prepared by first adding the PVA to water in the specified proportions and mixing for 2 minutes. The powder is gently added to the cold water to avoid the formation of lumps as it becomes sticky and has the tendency to form lumps. This is necessary to prevent it from entraining the air. The coarse aggregate, fine aggregate, and cement were then added to the mix in the concrete mixer drum. Water was then added gradually while mixing until a homogenous concrete mixture was obtained. For the specimens used for the compressive strength test, the concrete was then placed into 150mm x 150mm x 150mm cube moulds and adequately compacted with the aid of a compacting rod. This same procedure was also used when preparing the 150mm diameter cylindrical specimens for the split tensile test. As regards the specimens for the pull-out tests, 12mm diameter reinforcement cut into 450mm height was inserted into the cubic mould before the concrete was placed. It is shown in Figure 11.

Figure 11: Cleaning of moulds to receive mixed concrete.
Source: Authors, (2025).

III.2.3 WORKABILITY TEST

The slump test was carried out on the different batches of concrete produced to obtain a workable concrete using a 300mm high slump cone and tamping rod. The test was carried out in line with B.S. 1881: Part 102: 1983. It is depicted in Figure 12.

Figure 12: Workability of concrete.
Source: Authors, (2025).

III.2.4 DE-MOULDED SPECIMEN AND CURING

A total of 20 numbers of concrete cubic specimens of 150x150x150 mm were produced for the compressive test. Similarly, another 20 cubic specimens with 12mm rebars inserted when the concrete was placed were produced to carry out the pull-out test to check for the bond strength of the concrete and reinforcement. A total of 12 numbers of cylindrical specimens of 150 mm diameter and height of 300 mm were produced to aid out the split tensile test. All the specimens produced were de-moulded, placed into the curing tank, and cured for 7 and 28 days respectively. It is displayed in Figure 13.

Figure 13: Specimens and curing.
Source: Authors, (2025).

IV. RESULTS AND DISCUSSIONS

IV.1 WORKABILITY

Workability is the ease with which concrete mixes can be compacted. The Slump test is a common method for determining the workability of a wet concrete mix. The slump test was performed conforming to B.S. 1881: Part 102: 1983. The slump test is the most effective method for verifying the workability of concrete both in the lab and on the job site. The slump test is a handy control test that provides the workability result. In this experiment, the effects of PVA powder on concrete workability were investigated. The slump values of each of the specimens are given in Tables 4 and 5, which show the slump values and water-to-cement (w/c) ratios for different concrete mixtures.

As shown in Table 4, it can be observed that workability of the cubical sample decreased from 50mm to 21mm as the PVA content increased from 0% to 1%, while workability is increased from 21mm to 124mm as the PVA content increases from 1% to 2%. The workability of the cylindrical specimen rose from 15mm to 80mm as the PVA concentration increased from 0% to 2%, as shown in Table 5. This demonstrates that the concrete's ability to be worked has risen as a result of employing higher PVA addition rates. The results of [38], who discovered that adding more water makes the mixture more workable, lend credence to this assertion.

The rise in slump value indicates that the PVA addition has enhanced the concrete's workability by making it more fluid and manageable. The fact that PVA, a polymer that dissolves in water and functions as a dispersion, helps to separate the particles in concrete mixes and lowers viscosity, may help to explain this. The fact that the water-to-cement (w/c) ratio remained constant throughout all combinations is significant since it shows that an increase in water content was not the cause of the rise in slump value. This is important because concrete's strength and durability might be compromised by adding additional water to it.

Table 4: Slump test for the cubical mix.

Percentage PVA Dosage	Slump (mm)	w/c Ratio	Slump	Consistency grade
CP 0	50	0.65	True	Stiff
CP 0.5	25	0.65	True	Stiff
CP 1	21	0.65	True	Stiff
CP 1.5	66	0.65	True	Plastic
CP 2	124	0.65	Shear	Plastic

Source: Authors, (2025).

Table 5: Slump test for the cylindrical mix design.

Percentage PVA Dosage	Slump (mm)	w/c Ratio	Slump	Consistency grade
T0	15	0.65	True	Stiff
T1	35	0.65	True	Stiff
T2	80	0.65	Shear	Plastic

Source: Authors, (2025).

IV.2 COMPRESSIVE STRENGTH TEST

The concrete specimens' compressive strength was tested in line with the BS EN 12390-3:2019 standard. The concrete specimens were tested by putting them in a compression testing machine and applying a compressive force till failure. The compressive strength of the concrete was then estimated by dividing the greatest load applied to the specimen by its cross-sectional area. The compressive strength was determined at 7 and 28 days after casting and the results are presented in Figure 14.

It is obvious that the addition of PVA had an influence on the strength of the concrete at both the 7-day and 28-day marks based on the compressive strength findings of the experiment to explore the effect of PVA on concrete. The CP0.5 mix exhibited the maximum compressive strength after 7 and 28 days, with compressive strength values of 18.00 N/mm^2 and 24.98 N/mm^2. As compared to the control (CP0) mixes, which had compressive strength values of 16.25 N/mm^2 and 20.65 N/mm^2, this was a substantial improvement. At the 7-day point, the compressive strengths of the CP1 and CP1.5 mixtures were 13.52 N/mm^2 and 12.59 N/mm^2, respectively. At the 7-day point, the CP2 mix's compressive strength was the lowest, at just 8.42 N/mm^2. Additionally, at the 28-day point, the compressive strength values of the CP1, CP1.5, and CP2 mixtures were 19.45 N/mm^2, 17.58 N/mm^2, and 11.13 N/mm^2 respectively.

It can be inferred that the maximum compressive strength of concrete occurs at 0.5% addition of PVA to the concrete mix. This therefore suggests that the optimum compressive strength of concrete is attained at 0.5 PVA addition to concrete. This finding is consistent with those of [39-41]. Nevertheless, as demonstrated in the CP1, CP1.5, and CP2 mixes, the impact of PVA powder on compressive strength tends to decrease at greater concentrations. As indicated in CIP- (Concrete in Practice) and the American Society for Testing and Materials (ASTM C31/39), an average value of 15N/mm^2 may be utilised for Non-Critical Structural Works. Values more than 15N/mm^2 are ideal for Critical Structural Works, whereas values less than this benchmark are suitable for Non-Critical and Non-Structural Works. As illustrated in Figure

14, up to 1.5% addition of PVA with cement is suitable for critical structural works. However, as seen in Figure 16, PVA is unsuitable for reinforced concrete structural works, because its addition to reinforced concrete mixes does not bond effectively.

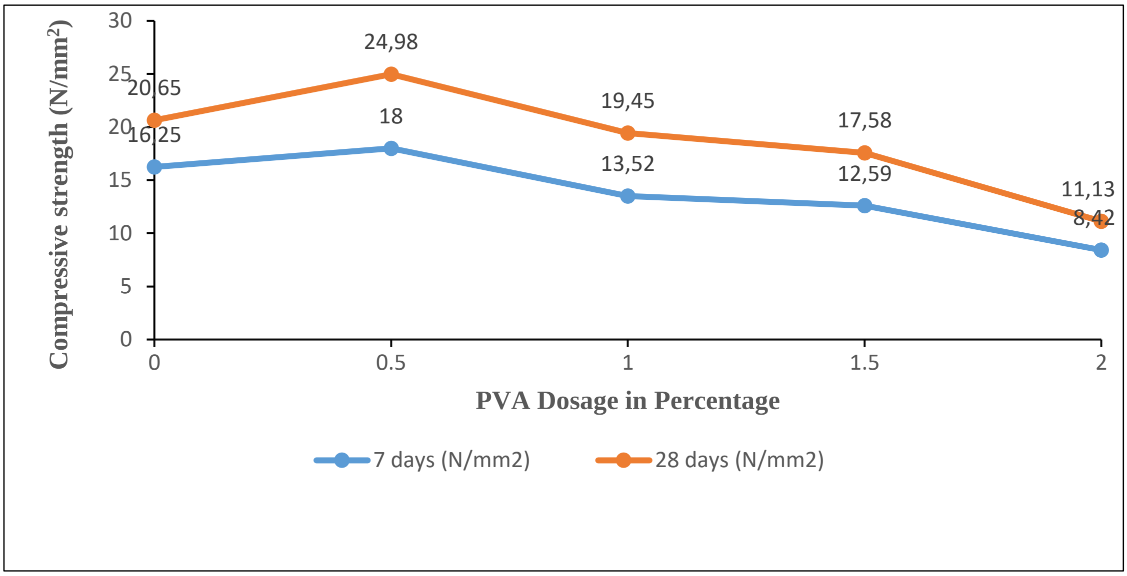

Figure 14: Compressive strength values at 7 and 28 days.
Source: Authors, (2025).

IV.3 TENSILE STRENGTH TEST

The concrete sample's tensile strength was evaluated using the BS EN 12390-6 standard. The concrete specimens were tested by putting them in a split tensile testing machine and applying a tensile force till failure. Three cylinders each were cast for each percentage ranging from 0% to 2% at 7 and 28 curing days. The tensile strength of the concrete was estimated by dividing the greatest load applied to the specimen by its cross-sectional area. Tensile strength was measured seven and twenty-eight days after cure. The tensile test results are presented in Figure 15.

From Figure 15, it can be observed that the tensile strength test results increase with increased percentage replacement of cement with PVA. As demonstrated by the rise in strength from T0 to T1 and T2, the tensile strength of the concrete rose as the proportion of PVA increased. At 7 days, the tensile strength of the control mix (T0) was 1.31 N/mm^2, but the strength of the mix containing the least quantity of polyvinyl alcohol powder (T1) was 1.40 N/mm^2, suggesting a 7% increase. The tensile strength of the mix with the highest concentration of polyvinyl alcohol powder (T2) was 1.57 N/mm^2, representing a 20% increase over the control mix. The tensile strength of the control mix (T0) increased to 1.61 N/mm^2 after 28 days, whereas the strength of the mix with the lowest amount of PVA (T1) increased to 2.17 N/mm^2, a 35% increase. The tensile strength of the mix with the greatest proportion of PVA (T2) was 2.22 N/mm^2, an increase of roughly 38% above the control mix. This implies that as the concentration of PVA in the concrete grows, so does its tensile strength. These results conform to the findings of [42].

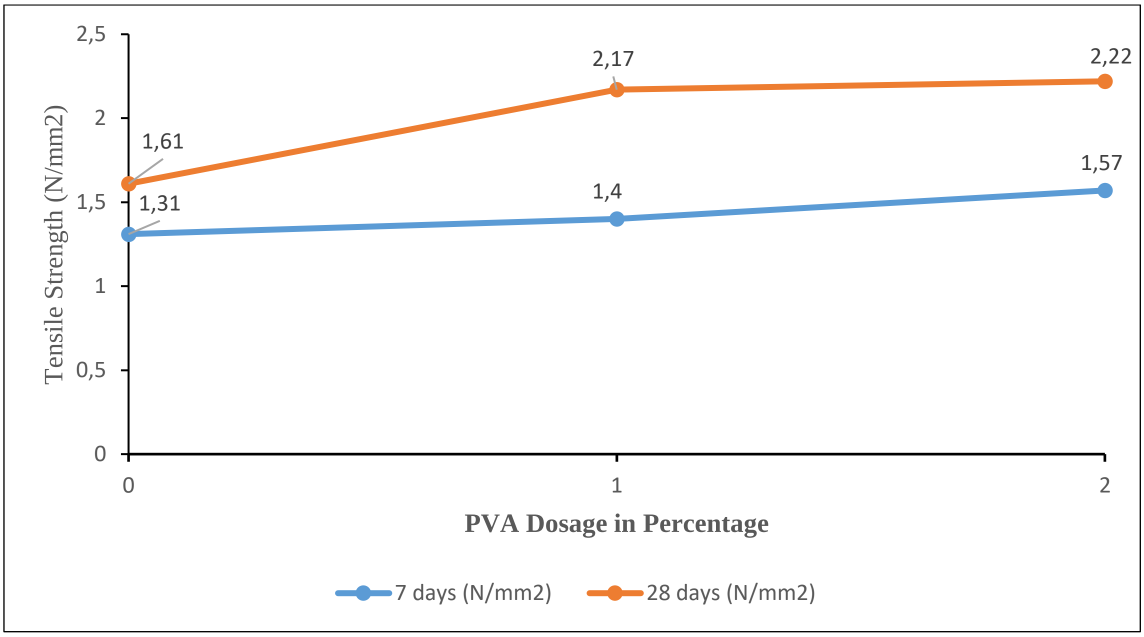

Figure 15: Tensile test results after 7 and 28 days.
Source: Authors, (2025).

IV.4 PULL-OUT (BOND) TEST

A pull-out test is a method for determining the strength of the connection between a concrete surface and a reinforcing bar or anchor. This test was typically carried out by fully inserting a steel rod into the concrete at 75mm from the bottom of the mould and then drawing it out at a steady rate of displacement while measuring the force needed. The specimen's bonding strength was tested at 7 and 28 days after casting. The pull-out test results are presented in Figure 16.

The control mix, CP0, had the strongest bond strength at 7 and 28 days, with pull-out strengths of 13.24 KN and 31.14 KN, respectively. Indicating that PVA does not bond well with reinforced concrete as the bonding strength is decreased as the amount of PVA powder in the mixture rises. For instance, the pull-out values of 12.75 KN at 7 days and 16.77 KN at 28 days, showing a 3.7% and 46% decline, respectively, respectively, the CP0.5 mix demonstrated weaker bond strength than the CP0 mix. The result remained at higher polyvinyl alcohol powder concentrations, with CP1, CP1.5, and CP2 combinations all displaying weaker bonds after 7 and 28 days. The CP2 mix had the weakest binding, with pull-out strengths of 1.47 KN at 7 and 28 days, an 85.13% decrease. This result corroborates the findings of [36] that PVA has a greater impact at younger ages when cement hydration has not yet been fully set. According to the results, adding PVA to concrete can weaken the bond that holds reinforcing bars to the concrete. With higher PVA percentages, the bonding strength was more noticeably reduced.

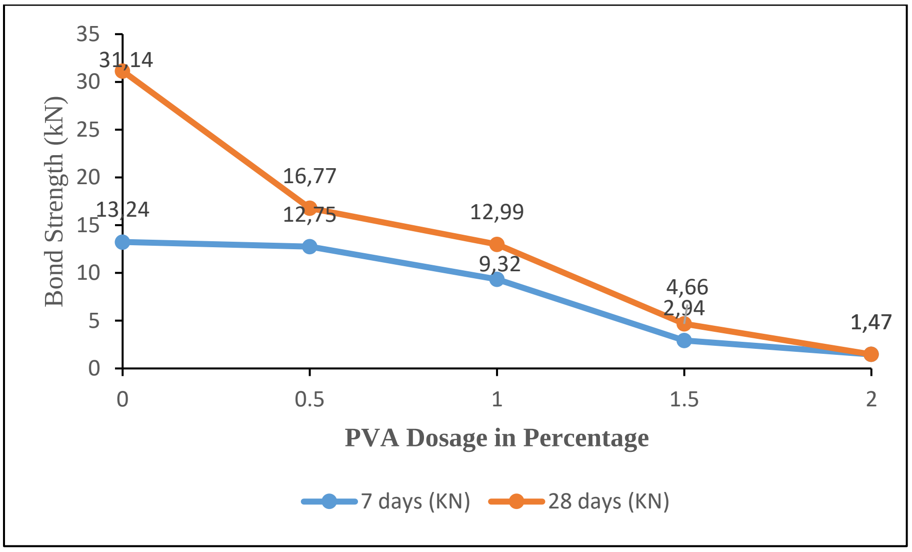

Figure 16: Pull out strength results after 7 and 28 days.
Source: Authors, (2025).

V. CONCLUSIONS

The following conclusions are drawn from the study's findings: The addition of PVA to the concrete mix has a significant influence on the workability of the concrete. The slump values of the concrete mixes increased as the amount of PVA was increased with constant water-to-cement (w/c) ratios. This implies that PVA acts as a dispersion, helping in particle separation in the concrete mix and decreasing viscosity, hence improving workability.

The maximum compressive strength of concrete occurs at 0.5% PVA application to the concrete mix. This implies that the optimal compressive strength of concrete is obtained with 0.5 PVA dosage. Also, the tensile strength of concrete increases with increasing PVA doses. Besides, the bonding strength between the concrete and the reinforcing bar is decreased when PVA is added to it.

The findings revealed that the bonding strength of concrete reduces by 46% with a 0.5% PVA admixture and keeps declining as the PVA dose increases. This implies that regardless of PVA dosage in a concrete mixture, there is a significant decline in bonding strength in concrete and reinforcement. The study therefore recommends that PVA should be applied for non-structural concrete works such as mass or plain concrete. This may be accomplished through the application of 0.5% doses of PVA in plain concrete mixes by Builders and Engineers to enhance the compressive strengths of the concretes produced.

VI. AUTHOR'S CONTRIBUTION

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