Journal of Engineering and Technology for Industrial Applications

ISSN ONLINE: 2447-0228

ITEGAM-JETIA

Manaus, v.10 n.48, p. 145-154. July/August, 2024.
DOI: https://doi.org/10.5935/jetia.v10i48.978

RESEARCH ARTICLE OPEN ACCESS

INVESTIGATING THE EFFECT OF TARTARIC ACID ON CONCRETE PRODUCED IN TROPICAL CLIMATES

Aliu Soyingbe[1], and Dele Simeon*[2]

[1,2] Department of Building, University of Lagos, Lagos, Nigeria.

[1]http://orcid.org/0000-0002-7992-6556, [2]http://orcid.org/0000-0002-3927-754

Email: asoyingbe@unilag.edu.ng, *dsimeon@unilag.edu.ng

ARTICLE INFO

Article History
Received: November 29th, 2023
Revised: July 08th, 2024
Accepted: August 15th, 2024
Published: August 30th, 2024

Keywords:
Dosage,
Ready-mix concrete,
Setting time,
Tartaric Acid,
Tropical climates.

ABSTRACT

The perpetual gridlock of Metropolitan Lagos is well-known, particularly during chaotic rush hours. As such, construction projects encounter difficulties with material transportation as well as rapid delivery of ready-mix concrete to construction sites located in this city. To achieve concrete that allows for long-distance transportation and lessens the impact of hot weather on concrete, this study investigated the performance of TA in concrete produced in tropical and congested climates and recommended suitable dosages and appropriate times of addition for the desired outcome. The study produced a working sample of 117 concrete cubes using various doses of TA at 0, 0.5, 1, 1.5, and 2%. Findings revealed that TA is time and dosage-dependent. The findings also revealed that the addition of TA at 31.5°C causes set retardation and the setting time of each test sample was substantially increased with TA addition. Moreover, the compressive strength of concrete was increased by 70.8% when a 2% TA was added after a 3-minute delay. The study concludes that TA is an appropriate retarder for ready-mix concrete because it provides extended workability, slows the setting time in gridlocks, prevents concrete from hardening untimely, and counteracts the impact of hot weather by slowing the setting time.

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I. INTRODUCTION

The basic ingredients for the production of concrete are cement, water, and aggregates [1]. However, [2] noted that an admixture may be added to the mixture to modify its characteristics. Although cement is a chemically active ingredient, its reactivity is only triggered when it is combined with water. The setting process commences when water is added to a concrete mixture. This process occurs as a result of the heat of the hydration reaction of cement. According to [3], the factors responsible for the physical properties of concrete are the extent of hydration of cement and the resultant microstructure of the hydrated cement. The hydration reaction of these compounds occurs within a certain time frame, and the formation of the products of the reaction results in the setting of the cementitious material, consequently causing a degree of hardness over time. The setting times of concrete and cement are categorized into the initial setting times and the final setting times. While the loss of plasticity is measured by the initial setting time, the gain of a particular hardness is measured by the final setting time. According to [ASTM C191-92], as cited in [4], the initial setting time can be seen when the Vicat's needle gets 25 millimeters of penetration while the final setting time is when the Vicat's needle cannot penetrate. Admixtures are known to improve the performance of concrete and are available in a wide variety of types and used for diverse applications. [5] buttressed that in order to improve particular qualities of the freshly mixed and cured concrete, additives, whether synthetic or natural, are included during the mixing process. Meanwhile, [6] notes that concrete admixtures are considered to be the most successful and extensively used solutions for improving concrete workability. Accordingly, [7] opines that admixtures are used to increase workability, to retard or accelerate the time of initial setting; to modify the rate or capacity for bleeding, to reduce segregation, to accelerate the rate of strength development at early ages, etc. One such admixture that retards the setting time of concrete is retarders.

Retarders are admixtures that extend the period in which the mix changes from the plastic to the rigid state.

The use of ready-mix concrete has obtained a dominant place in the Nigerian construction industry as it facilitates high speed of construction which is required in many construction projects. In most construction projects, ready-mix concrete is purchased from concrete suppliers who have their batching plants offsite at a distant location hence requiring transportation of concrete to the site. However, the traffic situation poses several problems to the transportation of concrete over long distances leading to a high probability of it setting in the truck when traffic congestion is high. Hence, a need to use retarders to curtail the menace. According to [8], transportation poses to be a challenge as a great deal of productive man-hours is wasted in traffic congestion in the commercial city of Lagos, Nigeria. Meanwhile, [9] opine that the nominal initial setting time for concrete is 30 minutes. [10] examined how superplasticizers and retarders influenced the characteristics of concrete with a 30 MPa specific strength. The findings indicated that combining a superplasticizer and a retarder might increase the workability of concrete. The characteristics of concrete produced by combining natural and retarded ready-mix concrete with a reverted fresh mix of concrete were examined [11]. The findings indicated that the concrete's workability, setting time, and compressive strength were all within acceptable bounds.

Retarders are generally categorized into two groups which are the organic and the inorganic chemicals. [12] classified retarders into three types, namely: Type B which simply retards the hydration of Portland cement; Type D which not only retards the hydration but also acts to disperse the cement particles thereby providing water reduction; and Type G which is a high range water reducing and set retarding admixture. According to [12] and [13], Type B retarders are Lignin, Borax, Sugars, Tartaric acids, and Salts. Tartaric acid is an organic retarder under the hydroxycarboxylic acid group which are characterized by carboxyl groups (-COOH) and hydroxyl groups (OH). It is a simple hydroxycarboxylic acid which has a chemical formula $C_4H_6O_6$ with two carboxyl (-COOH) and hydroxyl (OH) groups each. The most important step in tartaric acid inhibition is formation of calcium tartrate, but it has been observed that tartaric acid only exhibits a dissolution-precipitation mechanism for C_3A [14]. The effects of retarding admixture on the setting time of concrete are dependent upon the type of cement, mix proportions used, the dosage of the admixture, time of addition to the mix, the ambient temperature, and curing conditions [15, 16].

Tropical climates usually have distinct rainy and dry seasons and are characterized by high temperatures all year round. The tropical climates in Lagos-state, and most parts in Southwest, Nigeria throughout the year have a mean ambient temperature of about 30ºC. [16] are of the view that ambient temperature could be as high as over 43ºC in the extreme North Eastern part of the country. Thereby classifying concrete works done in these regions as hot weather concreting and as earlier stated, the high temperatures in these regions will result in rapid loss of water and acceleration in the setting of concrete causing thermal and plastic cracking, reduction in ultimate strength. [17] opine that concrete has a stronger compressive strength at low temperatures than it does at normal temperature. The use of retarders ameliorates the adverse effect of high temperature, as well as prolongs the initial setting time of concrete, thereby providing a solution to the problems associated with hot weather concreting and transportation of ready-mixed concrete. The type of cement, admixture dosage, mix proportion, time of addition to the mix, and ambient temperature are all factors that determine the effects of retarders on the setting time of concrete. In order to address the problems and provide recommendations for the use of retarders, the study seeks to investigate the effects of TA retarder on concrete made with a 32.5 grade, Ordinary Portland Cement (OPC) using a specific mix ratio so as to recommend suitable dosages and appropriate time of addition required to attain the desired outcome. The objectives of the study are to; determine the workability of concrete produced with varied percentages of TA retarder, determine the setting times of concrete produced with different percentage dosages, and establish the compressive strength of concrete produced with varied percentages of TA doses in tropical climates. The study is significant in tropical climates because TA improves workability, lowers the chance of early setting, enables better placement, and guarantees high-quality construction when used in ready-mix concrete.

II. MATERIALS AND METHODS

This section discusses the materials and methods used to conduct the study. The study is purely experimental and conducted in Lagos state, Nigeria. Lagos State which ranks among one of the six states in south western, Nigeria is situated in a tropical region and close to the Atlantic Ocean's Gulf of Guinea shoreline. The materials and methods are discussed in the following sub-sections.

II.1 MATERIALS

The materials used to carry out the investigation comprised: Ordinary Portland cement, fine aggregate, coarse aggregate, tartaric acid, and water. The cement used was OPC (Grade 32.5R) obtained from Lafarge PLC with a trade name “Elephant Classic” and conforms to the requirements of [18]. The fine aggregate used for the study was natural sharp river sand which was obtained from the Ogun River basin at Ibafo in Ogun state. This was dried and sieved using a 5mm BS 812 sieve in order to remove large aggregates and impurities. It was confirmed that the sand was free from deleterious substances that are liable to lead to unsoundness or react in a harmful way with the concrete. Besides, the Sharp sand did not contain particles exceeding 5mm in size and was in conformity with [19]. The coarse aggregate used was crushed granite with a maximum normal size of 20mm and retained on a 10mm sieve minimum which conformed to [20]. It was in saturated surface dry condition before it was used in the mixing. The admixture used was 99% extra pure dl-Tartaric acid (synthetic) which is highly soluble in water and specifically prepared for research and development/lab use only. It was obtained from T. Saicon International LTD at Ojota, Lagos. The water used was clean portable water obtained from the faculty of Environmental sciences workshop, at the University of Lagos, Akoka, Yaba Local government area of Lagos state and it conforms to the specification of [21] for the production of concrete.

II.2 METHODS

The various laboratory procedures carried out are reported in the sub-sections.

II.2.1 Preliminary Investigation on the Materials

The laboratory test carried out on the aggregates is the sieve analysis to determine the particle size distribution of the aggregates. The apparatus used to achieve this test were sieve shaker, cleaning brush, weighing balance, hand scoop, a set of BS sieves, and a metal tray. The laboratory procedures are that the sieves of the sieve shaker were cleaned using a cleaning brush to remove particles struck in the openings. The weight of each sieve and receiving pan was measured and recorded. The sieves were arranged in descending order according to their sizes (10mm, 5mm, 2.36mm, 1.0mm, 0.6mm, 0.25mm and 0.075mm). The weighed specimen was kept on the top sieve (1000g for sharp sand and 3000g for granite) and the complete sieve was stacked on the sieve shaker. The shaker was then allowed to work for 5-10 minutes. The sieve stack was removed from the shaker and weighed together with the samples of aggregate retained and then recorded. The sharp sand and granite retained on each sieve and receiving pan (sample passing) were weighed and recorded separately. Then, the following parameters were determined as required on each aggregate

$$\text{Percentage weight retained} = \frac{((\text{mass of sample} + \text{container}) - (\text{mass of container})) \times 100}{Total\ mass\ of\ sample} \quad (1)$$

Percentage weight passing = (100 - % Weight retained on consecutive sieve)

The sizes of the values of percentage passing at 10, 30 and 60 represented as D10, D30 and D60 were obtained from a graph of percentage passing each sieve plotted against sieve sizes (particle size distribution curve) which is used to determine:

- Fineness modulus (FM) = $$\sum \frac{\%\ \textbf{Cumulative Weight retained from 10.0mm to 0.075mm}}{\textbf{100}} \quad (2)$$
- The coefficient of uniformity, $C_u = \frac{D60}{D10}$ (3)

II.2.2 Preparation of Concrete

A nominal concrete mix of ratio 1:2:4 was prepared with a water/cement (w/c) ratio of 0.5 was adopted for the study at a temperature of 31.5 ^{o}C. The concrete mix was prepared by adding the admixture. Tartaric acid (TA) was added at a dosage of 0% as the control sample, 1.0 and 2.0% of the cement weight. The choice of dosage was based on the research carried out by [22] which indicated that TA retarded the setting of concrete at a dosage of 1% of the weight of cement.

The addition of TA to each mix was done at different times which were:

i. at the time of direct mixing of the concrete with water
ii. 3mins after mixing
iii. 5mins after mixing

The properties of TA are given in the Table 1:

Table 1: Properties of Tartaric Acid (TA).

Retarder	Molecular weight	Melting Point (^{o} C)	Density	Water Solubility
Tartaric acid	150.0878	240-206	1.7598	139g/100 ml

Source: Authors, (2024).

II.2.3 Workability Test

The Slump test was carried out for each batch of fresh concrete produced in accordance with the provisions of [23]. The workability is determined after each percentage addition of TA. The apparatus used for the study are slump cone, non-porous base plate, measuring scale, and tamping.

II.2.4 Setting Time Tests

The apparatus used for determining the initial and final setting times of the concrete produced is the Vicat's apparatus, weighing balance, stopwatch, non-porous plate, enamel try, and trowel. Two sets of samples were studied. The first being, 650g of cement mixed to normal consistency without Tartaric acid (TA) while the second was 650g of cement mixed to normal consistency after which the retarder, TA, was then added. The test was carried out, ensuring that each penetration test was at least 5mm away from any previous penetration and at least 10mm away from the inner side of the mould. The test block was always in the moist cabinet except when penetration measurements were being taken. Vicat's approach was used to determine the initial and final setting time tests following the [25] method.

II.2.4.1 Determination of Initial Setting Time

The elapsed time between the initial contact of cement and water and the penetration of 25 mm is the Vicat's initial time of setting and it is measured by the loss in plasticity. The initial setting time was determined by interpolating to determine the time when a penetration of 25mm was attained.

II.2.4.2 Determination of Final Setting Time

The elapsed time between the initial contact of cement and water and the time of setting endpoint is the Vicat's final time of setting and it is measured by a gain of a particular hardness. The time of setting endpoint was considered as the first penetration measurement where the needle does not mark a complete circular impression on the surface of the specimen.

II.2.5 Compressive Strength Test

The apparatus used were concrete mould, tamping rod, trowel, and Avery compression machine. A total of 117 cubic samples with dimensions of "150×150×150mm" for the various testing requirements were used for the study. For the compressive strength test, three cubes were crushed for each curing age (7, 14, and 28 days) complying to the requirements of [24]. The average of the results of these three cubes was recorded as the compressive strength value at a specified age. The cubes were weighed before testing to determine the unit weight. It is calculated using the formula:

$$\text{Compressive strength} = \frac{maximum\ load\ (KN) \times 1000}{Crosssectional\ Area\ (mm^2)} \quad (4)$$

II.2.6 Percentage Increase in The Ultimate Strength of Concrete

This involves comparing the compressive strength of the samples with no retarder added (the control sample) to other samples with different quantity of TA added to the mix. The compressive strengths obtained from the cubes were used to determine the percentage increase in strength for each case of usage of TA.

$$\%\ \text{Increase in Ultimate Strength} = \frac{Ult.Strength\ of\ sample - Ult.Strength\ of\ Control\ sample}{Ult.Strength\ of\ Control\ sample} \times 100 \quad (5)$$

III. RESULTS AND DISCUSSIONS

The results are discussed under the following headings. This includes tests on fine and coarse aggregate (sieve analysis), tests on fresh concrete (workability), and tests on hardened concrete.

III.1 SIEVE ANALYSIS

The sieve analysis was to carried out to determine the particle size distribution of the fine and coarse aggregates used for the research.

III.1.1 Sieve Analysis of Fine Aggregate

This sieve analysis test of the fine aggregate (Sharp Sand) was carried out to determine the particle size distribution of the fine aggregate used, as well as determine its fineness modulus (FM) and coefficient of uniformity, Cu. 1000g of sand was used in carrying out this test and the result of the sieve analysis is presented in Table 2 and Figure 1 respectively.

Weight of Sand Used (A = 1000g)

Table 2: Particle Size Distribution of Fine Aggregate (Sand).

BS Sieve size, mm	Aggregate weight Retained (g),	Cumulative weight Retained (g), B	Percentage Cumulative weight Retained %	Aggregate weight passing (g) C = A- B	Percentage Passing, % (d) $=\frac{C}{A}$ **X 100**
10.00	0.00	0.00	0.00	1000.00	100.00
5.00	29.90	29.9	2.99	970.10	97.01
2.36	47.00	76.90	7.69	923.10	92.31
1.18	143.80	220.70	22.07	779.30	77.93
0.6	318.90	539.60	53.96	460.40	46.04
0.3	285.50	825.10	82.51	174.90	17.49
0.15	131.40	956.50	95.65	43.50	4.35
0.075	23.20	979.70	97.97	20.30	2.03
Pan	7.4	987.10			

Source: Authors, (2024).

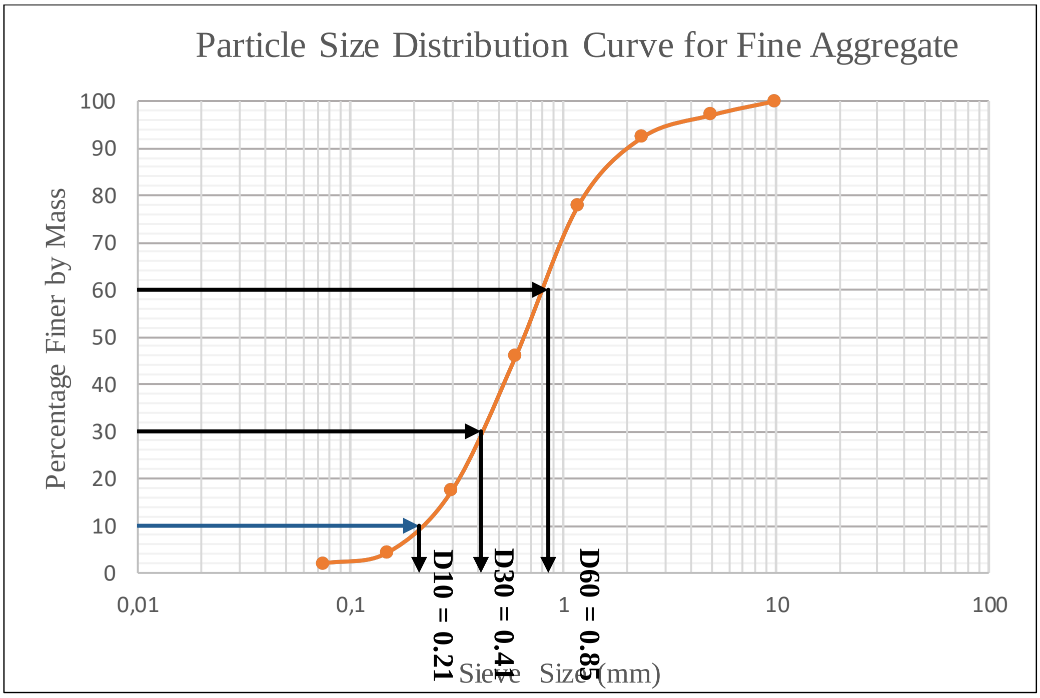

Figure 1: Particle size distribution curve of fine aggregate used for the research.

Source: Authors, (2024).

- Fineness modulus (FM) =

$$\sum \frac{\text{\% Cumulative Weight retained from 10.0mm to 0.075mm}}{100} = \frac{2.99+7.69+22.07+53.96+82.51+95.65+97.97}{100} = 3.63 \quad (6)$$

This means that the average fine aggregate size is within the 3rd and 4th sieve. That is, the average aggregate size is between 0.3mm and 0.6mm. And from the value of the fineness modulus, it is a medium sand.

- Coefficient of uniformity, $C_u = \frac{D60}{D10} = \frac{0.85}{0.21} = 4.05$ (7)

Since C_u>4, the sand is well-graded. Cu values between 4 and 6 are regarded as well-graded soil, whereas values under 4 are regarded as poorly-graded soil [26]. Therefore, the fine aggregate used was a well-graded medium sand.

III.1.2 Sieve Analysis of Coarse Aggregate

This test was carried out to determine the particle size distribution of the coarse aggregate used as well as determine its fineness modulus (FM) and coefficient of uniformity, Cu. Granite of 3000g was used in carrying out this test and the result of the sieve analysis is presented in Table 3 and Figure 2 respectively.

Weight of Granite Used (A = 3000g).

Table 3: Particle Size Distribution of Coarse Aggregate (Granite)

BS Sieve size, mm	Aggregate weight Retained (g),	Cumulative weight Retained (g), B	Percentage Cumulative weight Retained %	Aggregate weight passing (g) C = A- B	Percentage Passing, % (d) $=\frac{C}{A}$ X 100
25.0	0.00	0.00	0.00	3000.00	100.00
19.0	0.00	0.00	0.00	3000.00	100.00
14.0	13.6	13.6	0.45	2986.40	95.55
12.5	82.6	96.2	3.21	2903.80	96.79
10.0	835.6	931.8	31.06	2068.20	68.94
5.0	1880.6	2812.4	93.75	187.60	6.25
2.36	148.0	2960.4	98.68	39.60	1.32
Pan	32.3	2992.9			

Source: Authors, (2024).

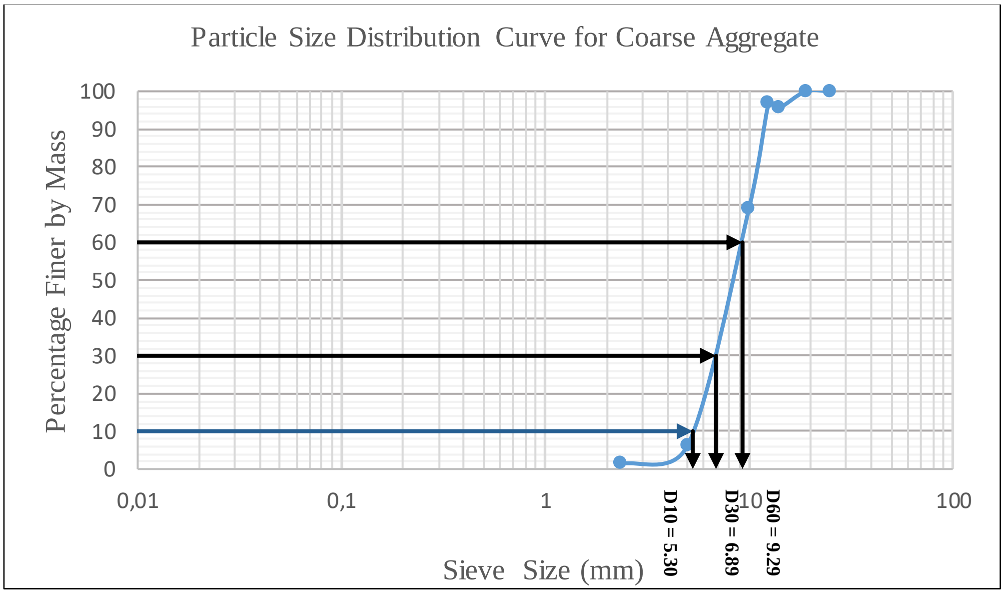

Figure 2: Particle size distribution curve of coarse aggregate used for the research.
Source: Authors, (2024).

- Fineness modulus (FM) =

$$\sum \frac{\text{\% Cumulative Weight retained from 25.0mm to 2.36mm}}{100} = \frac{0.00+0.00+0.45+3.21+31.06+93.75+98.62}{100} = 2.27 \quad (8)$$

This means that the average fine aggregate size is within the 2rd and 3rd sieves. That is, the average aggregate size is between 5.0mm and 10.0mm.

- Coefficient of uniformity, $C_u = \frac{D60}{D10} = \frac{9.29}{5.30} = 1.75$ (9)

Since C_u<4, the sand is uniformly graded. When the soil is well-graded, the coefficient of curvature (Cc) must range from 1 to 3, and when the soil is badly graded, Cc must be less than 1 [26]. Therefore, the coarse aggregate used was a uniformly graded coarse aggregate.

III.2 TEST ON FRESH CONCRETE

III.2.1 WORKABILITY OF CONCRETE

The workability of each concrete specimen was conducted using the Slump test [23]. The temperature reading recorded during this test was 31.5 ᵒ C. The results obtained for each sample are shown in Table 4. The result indicates that workability is very low in the control specimen. The result further indicates that workability is directly proportional to the dosage of TA among Specimens. This indicates that workability increases as the TA dose increases among specimens A and C. Meanwhile, there is an inverse relationship among specimen B, indicating that the lower the addition of TA, the higher the workability.

Table 4: Slump Test of Various Concrete Samples.

Sample Type	Delay before Addition of TA (min)	Dosage of TA (% wt of Cement)	Slump	
			Slump(mm)	Degree of workability
Control	-	0	15	Very low
A1	0	0.5	62	Medium
A2	0	1	115	High
A3	0	1.5	119.2	High
A4	0	2	125.4	High
B1	3	0.5	130	High
B2	3	1	165	High
B3	3	1.5	80	Medium
B4	3	2	65	Medium
C1	5	0.5	60	Medium
C2	5	1	68	Medium
C3	5	1.5	90	Medium
C4	5	2	113	High

Note: A Slump value of 0-25mm indicates Very Low; 25-50mm indicates Low; 50-100mm indicates Medium; and 100-175mm indicates High.

Source: Authors, (2024).

III.2.2 setting time test

The initial and final setting times of the various samples were determined using Vicat's Apparatus, and following the procedures of [27] in the Test for Setting Time, and the results are displayed in Table 5. Table 5 depicts that the addition of TA causes set retardation as the setting time for each of the test samples was substantially increased compared to that of the control sample. It is evident that for a 1:2:4 concrete mix, a 1% dose of TA results in higher retardation for all delays in times of addition compared to a 2% dose. It was also observed that a 2% dose of tartaric acid to the cement paste used for the setting time test resulted in an unusual dryness of the paste, but this was not observed when a 2% dose was added to the 1:2:4 concrete mix as the resulting concrete became more workable. The setting time results validate the study's arguments that TA is an appropriate retarder for ready-mix concrete because it provides extended workability, slows the setting time in congestion and traffic jams, prevents concrete from hardening untimely, counteracts the impact of hot weather by slowing the setting time, and provides improved control over quality by guaranteeing accurate concrete placement and finishing. These findings corroborate the assertions of [28] that retarders prolong the amount of time that concrete may be finished, put, and transported. Moreover, [22] substantiates that TA is a powerful inhibitor of OPC hydration. It chemically reacts with cement mineral phases to generate calcium tartarate hydrate. This chemical covers the surface of cement granules, preventing hydration. As a result, hydration is slowed.

Table 5: Setting Time Test for Various Sample Types.

Sample Type	Delay before Addition of TA (min)	Dosage of TA (% wt of Cement)	Setting Time (min)	
			Initial	Final
Control	-	0	192	289
A1	0	0.5	417	932
A2	0	1	617	1463
A3	0	1.5	570	1412
A4	0	2	512	1397
B1	3	0.5	775	1499
B2	3	1	1004	1849
B3	3	1.5	612	1111
B4	3	2	267	582
C1	5	0.5	515	933
C2	5	1	799	1550
C3	5	1.5	417	793
C4	5	2	304	664

Source: Authors, (2024).

III.3 TEST ON HARDENED CONCRETE

The compressive test results after curing at 7, 14, and 28days are presented and discussed in the following sections

III.3.1 COMPRESSIVE STRENGTH TEST

The results of the test for compressive strength of the various dosages and times of addition of Tartaric Acid (TA) used in making the samples are presented in Table 6. A total of 117 concrete specimens of size 150mm×150mm×150mm were produced, and the compressive test was conducted on the specimens at 7, 14, and 28 days respectively in accordance with [29]. Then the average compressive strength was calculated for the respective ages of concrete samples. The various concrete samples are control samples with no addition of TA; Type A to which TA was added at 0.5, 1, 1.5, and 2% immediately after the cement came in contact with water, i.e., 0mins delay; Type B to which TA was added three minutes after cement made contact with water, i.e., 3mins delay at 0.5, 1, 1.5, and 2%; and Type C to which TA was added five minutes after cement made contact with water, i.e., 5mins delay at 0.5, 1, 1.5, and 2% respectively. The findings show that when the curing age increases, concrete's compressive strength typically rises regardless of the percentage replacement. This is in line with typical research on how concrete behaves as it ages. Moreover, the control specimen recorded the least using value among all the specimens produced. This suggests that the inclusion of TA enhances the strength of concrete. The result further indicates that specimen B4 at 2%TA addition after a 3-minute delay gave the highest value of compressive strength at all curing ages. It includes 23.7N/mm^2, 32.98, and 35.5N/mm^2 at 7, 14, and 28 days respectively.

Table 6: Compressive Strength of Concrete Specimen.

Sample Type	Delay before Addition of TA (min)	Dosage of TA (% wt of Cement)	Average Compressive Strength (N/mm^2)		
			7 Days	14 Days	28 Days
A1	0	0.5	14.96	20.23	23.95
A2	0	1	15.73	21.93	29.21
A3	0	1.5	15.22	21.02	29.43
A4	0	2	15.18	20.44	29.85
B1	3	0.5	15.88	21.59	27.99
B2	3	1	16.45	24.59	25.04
B3	3	1.5	20.22	29.5	31.95
B4	3	2	23.7	32.98	35.5
C1	5	0.5	21.1	24.33	26.95
C2	5	1	22.67	27.11	29.48
C3	5	1.5	22.55	28.86	30.05
C4	5	2	22.29	29.63	30.81

Source: Authors, (2024).

III.3.2 Compressive Strength at Immediate Addition of TA

Figure 3 gives a representation of the gain in compressive strength of the control sample with 0% dosage of TA and that of samples type A to which 1% and 2% of TA were added to the concrete mix immediately after cement made contact with water. It can be seen that compared to the control sample, samples Type A had slightly higher compressive strengths on 7 and 14 days of curing, but on the 28th day, these samples had significantly higher strength than the control sample for both 1% and 2% dosage of TA. This signifies that the addition of Tartaric Acid to a concrete mix causes an increase in the ultimate strength.

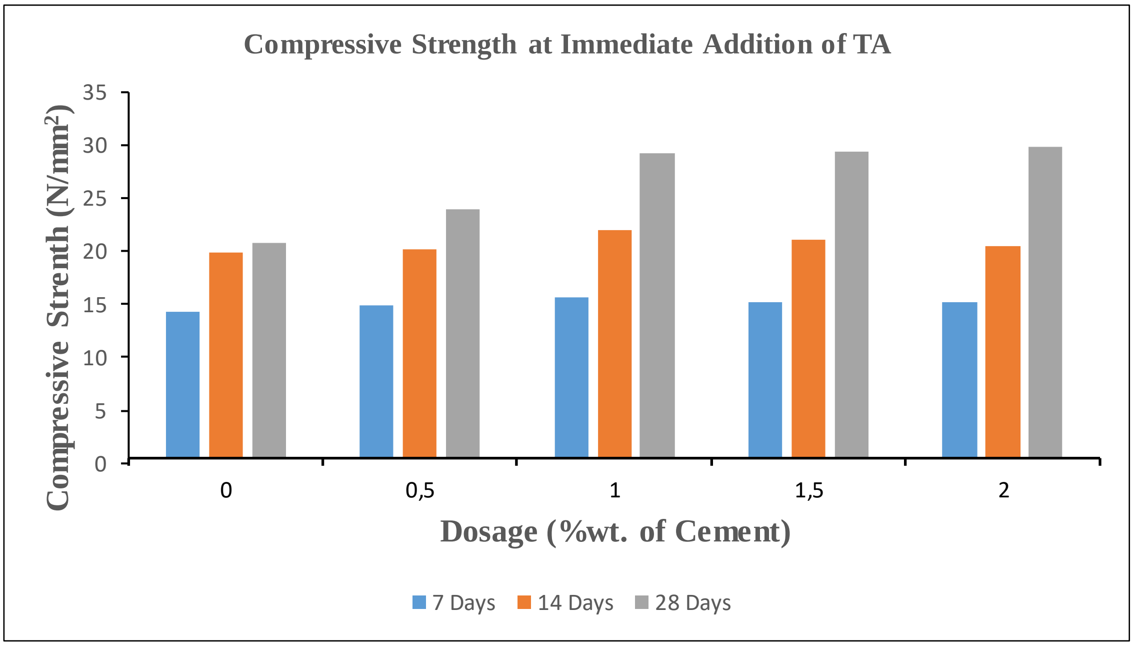

Figure 3: Relationship between the compressive strength of concrete samples upon immediate addition of Tartaric Acid (TA) at different dosages by percentage weight of cement in concrete mix.
Source: Authors, (2024).

III.3.3 Compressive Strength at 3 Minutes Delay Before the Addition of TA

Figure 4 gives a representation of the gain in compressive strength of the control sample with 0% dosage of TA and that of samples type B to which 1% and 2% of TA was added to the concrete mix 3 minutes after cement made contact with water. It was observed that there was a significant increase in compressive strength for all respective ages of the Type B samples, compared to the control samples. This indicates that the addition of Tartaric Acid to a concrete mix after a 3-minute delay causes an increase in the ultimate strength at 1% and 2% dosages and that a higher dosage results in a significantly higher gain in compressive strength.

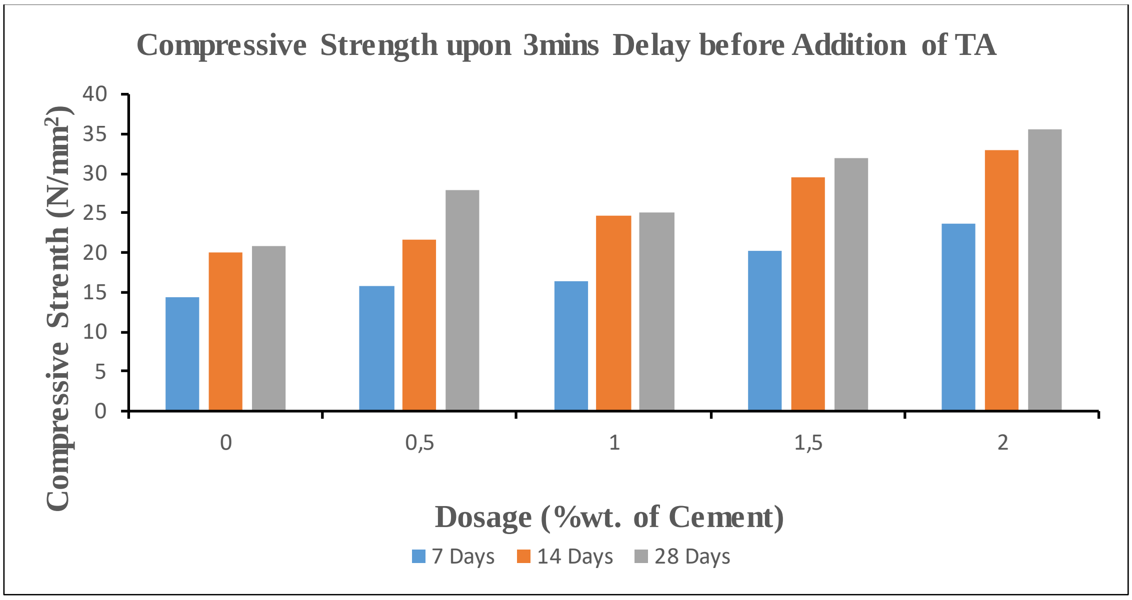

Figure 4: Relationship between the compressive strength of concrete samples upon a 3-minute delay before the addition of TA at different dosages by percentage weight of cement in the concrete mix.
Source: Authors, (2024).

III.3.4 Compressive Strength At 5 Minutes Delay Before the Addition of TA

Figure 5 gives a representation of the gain in compressive strength of the control sample with 0% dosage of TA and that of samples type C to which 1% and 2% of TA was added to the concrete mix 5 minutes after cement made contact with water. It can be clearly seen that type C samples had a significant increase in compressive strength for all respective ages of the samples, compared to the control samples, but the difference in strength for the two dosages TA was not high. This also signifies that the addition of Tartaric Acid to a concrete mix after 5 5-minute delay results in an increase in the ultimate strength at 1% and 2% dosages, with the higher dosage resulting in a slightly greater compressive strength.

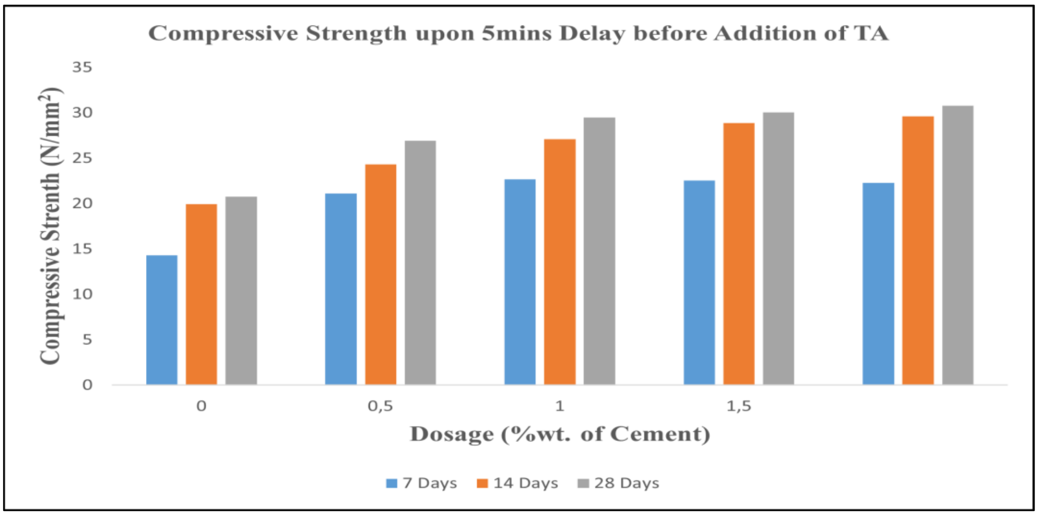

Figure 5: Relationship between the compressive strength of concrete samples upon 5-minute delay before the addition of TA at different dosages by percentage weight of cement in the concrete mix.
Source: Authors, (2024).

III.3.5 Percentage Increase in the Ultimate Strength of Concrete Specimen

Table 7 below shows the percentage increase in ultimate compressive strength of the various concrete samples used for the research, compared to that of the control sample. It can be clearly seen that the addition of TA resulted in a substantial increase in the ultimate compressive strength of all test samples.

From the results, the addition of 2% dose of TA 3 minutes after the cement of the mix makes contact with water results in a 70% increase in compressive strength, making it a highly effective dose. From the results of the compressive strength test, it can be inferred that in most cases, a 2% dose of Tartaric Acid will attain a higher increase in compressive strength for 1:2:4 concrete mixes as compared to a 1% dose for corresponding concrete ages.

Table 7: Percentage increase in ultimate compressive strength of concrete specimen.

Sample Types	Delay before Addition of TA (min)	Dosage of TA (% wt of Cement)	Average Ultimate Compressive Strength (N/mm^2), B	B-A	$\frac{B-A}{A}$	% Increase in Ultimate Compressive Strength $\frac{B-A}{A} \times 100$
A1	0	0.5	23.95	3.17	0.159	15.9
A2	0	1	29.21	8.43	0.406	40.6
A3	0	1.5	29.43	8.65	0.416	41.6
A4	0	2	29.85	9.07	0.436	43.6
B1	3	0.5	27.99	7.21	0.347	34.7
B2	3	1	25.04	4.26	0.205	20.5
B3	3	1.5	31.95	11.17	0.538	53.8
B4	3	2	35.5	14.72	0.708	70.8
C1	5	0.5	26.95	6.17	0.297	29.7
C2	5	1	29.48	8.7	0.419	41.9
C3	5	1.5	30.05	9.27	0.446	44.6
C4	5	2	30.81	10.03	0.483	48.3

Average Ultimate Compressive Strength of Control Sample (**A**) = 20.78 N/mm^2.

Source: Authors, (2024).

IV. CONCLUSIONS

Based on the findings arising from this study, the study makes the following conclusions.

The fineness modulus of the sharp sand and granites utilized were 3.63 and 2.27 respectively. Likewise, the uniformity coefficients of the sharp sand and granite utilized are 4.05 and 1.75 respectively. Additionally, there is a direct relationship between the percentage increase in TA addition and workability. Besides, the study notes that TA is an appropriate retarder for ready-mix concrete because it provides extended workability, slows the setting time in congestion and traffic jams, prevents concrete from hardening untimely, counteracts the impact of hot weather by slowing the setting time, and provides improved control over quality by guaranteeing accurate concrete placement and finishing. Moreover, the compressive strength of concrete is increased by 70.8% when a 2% dose of TA is added after a 3-minute delay. Therefore, TA is an effective retarder that increases the ultimate strength of concrete samples.

VI. AUTHOR'S CONTRIBUTION

Conceptualization: Aliu Soyingbe and Dele Simeon
Methodology: Aliu Soyingbe and Dele Simeon
Investigation: Aliu Soyingbe and Dele Simeon
Discussion of results: Aliu Soyingbe and Dele Simeon
Writing – Original Draft: Aliu Soyingbe and Dele Simeon
Writing – Review and Editing: Aliu Soyingbe and Dele Simeon
Resources: Aliu Soyingbe and Dele Simeon
Supervision: Aliu Soyingbe and Dele Simeon
Approval of the final text: Aliu Soyingbe and Dele Simeon

VII. ACKNOWLEDGMENTS

The authors wish to thank the Heads of the Department of Building, and Civil and Environmental Engineering Department, University of Lagos for their immense support towards the success of this research.

VII. REFERENCES

[1] Oladiran, O. J., Simeon, D. R., & Olatunde, O. A. (2020) Investigating the Performance of Palm KernelShells and Periwinkle Shells as Coarse Aggregates in Concrete. *Lautech Journal of Civil and Environmental Studies*, *4*(1), 123-133.https://doi.org/10.36108/laujoces/0202/40(0131)

[2] Alsadey, S., & Aljenkawi, A. S. (2021). Retarder Chemical Admixture: A Major Role in Modern Concrete Materials. *International Journal of Materials Chemistry and Physics*, *7*(1), 1-4.

[3] Duggal, S. K. (2010). *Building materials*. (3rd Revised Edition), New Age International Limited, New Delhi.

[4] Purnomo, J., Sumarni, S., & Saputro, I. N. (2019). Effect of citric acid on setting-time and compressive strength of concrete. *IOP Conference Series: Materials Science and Engineering*, *578*(1). https://doi.org/10.1088/1757-899X/578/1/012077

[5] Blankendaal, T., Schuur, P., & Voordijk, H. (2014). Reducing the environmental impact of concrete and asphalt: a scenario approach. *Journal of Cleaner Production*, *66*, 27-36.

[6] Şahin, H. G., Mardani, A., Özen, S., & Emin, A. (2023). Utilization of high-range water-reducing admixture having air-entraining agents in cementitious systems. *Journal of Building Engineering*, *64*, 105565.

[7] ACI Committee. (2016). 212, ACI 212. 3R-16 Report on Chemical Admixtures for Concrete. In *American Concrete Institute*.

[8] Bako, A. I., & Agunloye, O. O. (2017). Factors Influencing Road Traffic Delay: Drivers' Perspectives and Loss of Man-Hour Along Lagos-Abeokuta Expressway, Lagos, Nigeria. *Ethiopian Journal of Environmental Studies and Management*, *10*(5), 618-628.

[9] Greesan, R., Prathap, P., & Vijayakumar, R. (2014). Manufacturing of Concrete with Retarders. *International Journal of Scientific &*

Engineering Research, *5*(4), 1637-1639.

[10] Alsadey, S. (2015). Effect of superplasticizer on fresh and hardened properties of concrete. *Journal of Agricultural Science and Engineering*, *1*(2), 70-74.

[11] Gebremichael, N. N., Karein, S. M. M., Karakouzian, M., & Jadidi, K. (2019). Investigation of setting time and compressive strength of ready-mixed concrete blended with returned fresh concrete. *Construction and Building Materials*, *197*, 428-435.

[12] ASTM, A. (2005). ASTM C494: Standard specification for chemical admixtures for concrete. *West Conshohocken, PA, USA: ASTM*.

[13] AASHTO. Standard specification for chemical admixtures for concrete. American 438 Association of State Highway Transportation Officials, AASHTO M194

[14] Bishop, M., & Barron, A. R. (2006). Cement hydration inhibition with sucrose, tartaric acid, and lignosulfonate: analytical and spectroscopic study. *Industrial & engineering chemistry research*, *45*(21), 7042-7049.

[15] Jackson, N., & Dhir, R. K. (1996). *Civil Engineering Materials* (5th ed.).

[16] Khan, B., & Muhammad-Ullah, M.-U. (2004). Effect of a Retarding Admixture on the Setting Time.of Cement Pastes in Hot Weather. *Journal of King Abdulaziz University-Engineering Sciences*, *15*(1), 63 79. https://doi.org/10.4197/eng.15-1.5

[17] Huo, Y., Sun, H., Lu, D., Chen, Z., & Yang, Y. (2022). Mechanical properties of concrete at low and ultra - low temperatures - a review. *Journal of Infrastructure Preservation and Resilience*. https://doi.org/10.1186/s43065-022-00063-4

[18] British Standard European Norm, (1995). Cement; Composition, specification and conformity criteria for common cements. BS EN 197-1, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K

[19] British Standard Institution, "Aggregates for concrete", London, BS EN 12620, 2013.

[20] British Standard European Norm, (1998). Tests for geometrical properties of aggregates; Determination of percentage of crushed and broken surfaces in coarse aggregate particles. BS EN 933-5, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

[21] British Standard European Norm, (2002). Mixing water for concrete; Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete. BS EN 1008-2, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

[22] Rai, S., Singh, N. B., & Singh, N. P. (2006). Interaction of tartaric acid during hydration of Portland cement. *Indian Journal of Chemical Technology*, *13*(3), 255 261.

[23] British Standard Institution "Testing Concrete - Method for determination of slump", London, BS1881 - 102: 1983.

[24] British Standard European Norm, (1995). Methods of testing cement; Determination of setting time and soundness. BS EN 196-3, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

[25] British Standard European Norm, (2002). Testing hardened concrete; Compressive strength of test. BS EN 12390-3, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K

[26] Salau, M. A., & Busari, A. O. (2015). Effect of different coarse aggregate sizes on the strength characteristics of aterized concrete. In *IOP Conference Series: Materials Science and Engineering*, 96(1), 012079. IOP Publishing.

[27] British Standard European Norm, (1995). Methods of t esting cement; Determination of setting time andsoundness. BS EN 196-3, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K.

[28] Kavathe, S. S., & Kulkarni, J. G. (2015). Retempering of Concrete Made by using Artificial Sand Containing Superplastciser & Retarder. *Int. J. Eng. Res.*, *4*, 716 720.

[29] British Standard European Norm, (2002). Testing hardened concrete; Compressive strength of test. BS EN 12390-3, BSI, Linfordwood, Milton Keynes MK14 6LE, U.K