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Research Article

Effect of retardant admixtures type and their using method on the behavior of concrete

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ABSTRACT

Construction sites may be exposed to crisis conditions during the casting process, resulting in delays of several hours and causing destruction of ready-mix concrete. This study suggests an experimental analysis of the possibility of using a specific additional dose of retardant admixtures, which may be used to ready-mix concrete before the initial setting of the concrete occurs. The effect of this additional dose on concrete characteristics in terms of workability, setting time, and compressive strength is also being studied. To conduct this investigation, three types of retardant admixtures from three branded companies were used. In addition, a penetration resistance experiment was conducted on the concrete to determine its setting time. The setting time of concrete was measured at different period intervals depending on when the additional dose of the retardant admixtures was added from the start of the concrete mixing. The results showed that concrete maintained proper workability for a period of more than five hours after using the additional dose of retarding admixtures. The additional dose of retarding admixtures not only delayed the concrete setting but also improved the compressive strength of the concrete. This implies that the use of an additional dose of retardant admixtures specifically tailored for ready-mix concrete is an effective option to avoid the return of ready-mixed fresh concrete.

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1. Introduction

Concrete is a main objective for building development and infrastructural progress all over the world as a result of its durability, strength, and being economical (Esfahani et al., 2021).

Admixtures are natural or manufactured chemicals or additives added during concrete mixing to enhance specific properties of the fresh and hardened concrete (Blankendaal et al., 2014). The use of admixtures in concrete allowed for increased workability and strength without raising the cement content or requiring more water. Retardant admixtures are used to slow down the setting time and to improve the primary flow capacity (Rohden et al., 2012). The output of the retardant relies on the chemical and mineralogical configuration of the cement and the content of admixtures (Belous et al., 2009). Lignosulfonic acids and their salts, hydroxyl-carboxylic acids and their salts, inorganic salts, phosphates and sugars and their derivatives are the major sources of materials, which form retardant compounds (Neville, 2013).

Several researchers have studied the factors that influence the behavior of the retardant admixtures through the hydration process, such as the cement form, the retardant form, the retardant quantity, and the temperature degree through adding the admixtures to the concrete (Khan, 2004). Ozturk and Baradan (2011) studied the impact of the form and excess dose of retardant admixtures on certain mechanical and microstructural properties of cement mortar. Results exhibited that cement mortars with retardant admixtures had greater strength rates by making a more normal microstructure with reduced porosity. Islam et al. (2019) examined the effect of the retarding super plasticizer on the workability

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of cement past, mortar, and concrete. The results showed that the workability of all mixtures was improved by the use of super plasticizers from different manufacturers. The results also determined that the properties of cement paste, mortar and concrete could be enhanced with the ideal dosage for each type of admixture. Alsadey (2013) investigated the effects of super plasticizer and retarder on the properties of concrete with a specific strength of 30 MPa. The results showed that the workability of concrete could be improved by adding a super plasticizer and a retarder.

Kubissa et al. (2021) investigated the effect of an air entraining admixture and citric acid as concrete setting retarder on concrete durability. The findings obtained indicated that citric acid applied at 0.2% of the cement weight clearly increased concrete's durability parameters and also decreased water absorption and air permeability. By incorporating an air entraining admixture, the opposite effect was achieved. The combined use of both additives led to an interaction between them, whose results were varied and dependent.

Souza et al. (2020) considered the role of chemical admixtures in producing large-scale buildings by 3D printed concrete. Results showed that chemical admixtures improved the fresh concrete rheological criteria, setting the desired quality, and preserving for longer periods the workability and build ability. Rohden et al. (2012) investigated the influence of chemical admixture form and dose mortar's on the mechanical properties of concrete. Results revealed that compressive strength values rose from 2% to 6% and flexural strength values rose from 1% to 6% due to the use of chemical admixtures.

In the field of concrete construction awareness of the setting characteristics of concrete is essential. It would help to plan the different stages involved in concrete building operations such as transportation, installation, compaction and concrete finishing (Brooks et al., 2000). Gnanaraj et al. (2020) investigated the effects of various mineral admixtures and chemical additives used in self-compacting concrete, as well as the changes in mechanical behavior caused by these admixtures. The outcomes showed that the use of a mineral additive such as rice husk ash increased the mechanical qualities of self-compacting concrete by up to 15% when compared to standard Portland cement. However, it was shown to have a highly flowable matrix with little chloride ion resistance. Fernandes and Guptha (2021) investigated the impact of recent chemical admixtures on the strength of cement mortar cubes. In comparison to the cubes evaluated without any admixtures, it was established that the inclusion of admixtures did not give excellent performance in the strength of mortars.

Researchers are looking for different ways to reduce the amount of fresh ready-mixed concrete returned, which has a negative impact on the environment and on the economy (Obla et al., 2007; Gonzalez et al., 2004; Suresh et al., 2016). To characterize the unused concrete returned to the truck facility, it was divided into 60%, which went directly to the landfill site. The remaining 40% was used to manufacture various products of concrete or recycled materials (Ferrari et al., 2014). Negasie et al. (2019) studied the properties of concrete made from mixing returned fresh mixture of concrete mixed with natural and retarded ready-mix concrete. The results showed acceptable values for workability, setting time, and compressive strength of concrete.

This paper investigates the effect of three types of retarding admixtures on the performance of concrete. Retarding admixtures from three branded companies were used to help concrete to remain fresh for a longer time. Nine mixtures were made with retardant admixtures, either once at the beginning of the mixing or by using a second additional dose of retardant admixtures at different times after mixing. The properties of those mixtures were compared with a control mixture that did not contain retardant admixtures. In terms of value, the determination of the concrete setting time was more important and necessary than the determination of the cement-setting time for construction workers. Penetration resistance monitoring was applied in several studies to assess the setting time of specific suspicion (Brooks, 2000; Suresh et al., 2016). The setting time of concrete in this study was measured by penetration resistance for all mixtures, as well as assigning workability and compressive strength to all mixtures.

2. Experimental program

2.1. Materials

Ordinary Portland cement (OPC), natural siliceous sand as a fine aggregate, gravel as a coarse aggregate and retardant chemical compounds have been used in this study. Class 42.5 N OPC meets the requirements of (E.S. 4765-1, 2012). The specific gravity and Blain fineness of OPC were 3.15 g/mm^3 and 3986 cm^2/g, respectively. Gravel with size 10 mm and sand were collected from Suez zone. Physical properties of used aggregates are described in Table 1. The particle size distribution of used aggregates shown in Fig. 1.

Potable water was used with no strange taste, color bouquet, or turbidity. Three types of retardant admixtures have been collected from three branded companies. The first admixture was (Plastimnt -AR340) collected from Sika, the second was (Addicrete BVSS-CMB) collected from CMB and the third was (Techno-mix 130 CR) collected from (MTC) company. The three admixtures were characterized by a dark brown color. Their relative density was about 1.1 ± 0.005 kg/L. The content of chloride was not more than 0.2%. The chemical compounds of the tree admixtures are shown in Table 2.

Table 1. Physical properties of fine and coarse aggregates.

No.	Property	Value	
		Sand	Gravel
1	Specific gravity	2.58	2.65
2	Bulk density (kg/m^3)	1555	1632
3	Fineness modulus	2.72	5.6
4	Absorption (%)	1.2	0.9

Table 2. Different components of used admixtures.

Component for retarding	in "Addicrete BVSS-CMB"	in "Plastimnt -AR340"	in "Techno-mix 130 CR"
Glucose polymers	5%	4%	7%
Salts of lignosulfonic acid	80%	82%	78%
Salts of hydroxylases carboxylic acids	15%	14%	15%

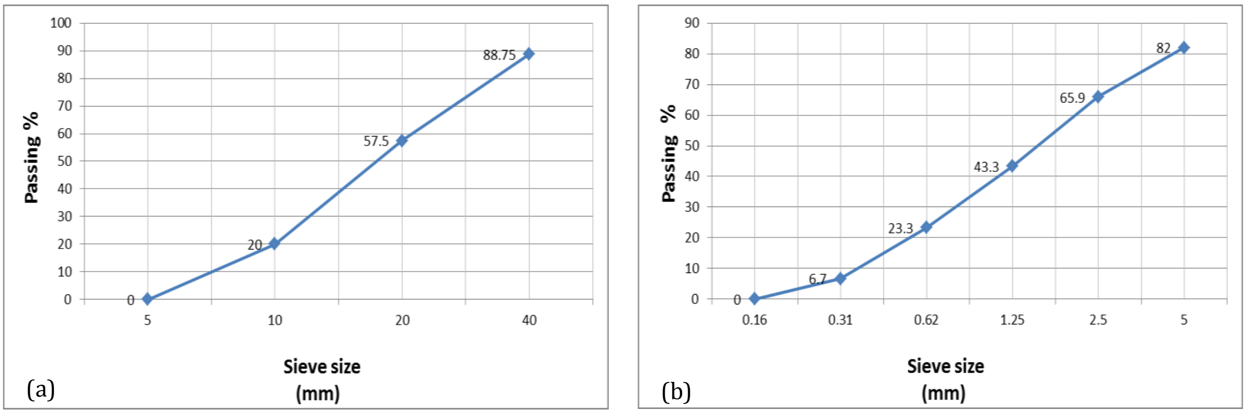

Fig. 1. Particle size distribution of used aggregates: (a) Sieve analysis for sand; (b) Sieve analysis for gravel.

3. Experimental Methodology

The impact of different types of retardant admixtures and how they're used on concrete behavior was studied. For this purpose, the effect of using three various types of retardant admixtures on ready -mix concrete has been studied at different periods since the beginning of the mixing process. The methodology included in this investigation was subdivided into two parts. Workability and setting time were performed in the first phase of the preliminary tests. The strength of specimens was evaluated in the second stage.

To determine the setting time for fresh concrete in this research, the penetration resistance test was applied in accordance with (ASTM C09, 2008). The concrete mixes were designed according to the ACI method (ACI 211.1-91, 1991) with a required compressive strength of 32 N/mm^2 and using a constant water/cement content of 0.4. Ten mixtures were prepared and 12 cubes 150x150x150 mm were cast for each mixture, with a total of 120 cubes. The mixture components of ten mixes are described in Table 3.

After casting and leveling the surface of the cubes, the front of the penetration tool was inserted on regular occasions to determine the force necessary for penetration as shown in Fig. 2. The concrete implantation process has been repeated and the relationship has been established between the reaction of the penetration device resistance and the time taken to reach the required values to achieve the initial and the final setting time of each mixture used in this study. The values of concrete setting time were recorded when the penetration resistance value was 3.5MPa (500 psi) as the initial setting occurred. The final setting was also reported when the resistance to penetration exceeded 27.5 MPa (4000 psi) (Suresh et al., 2016).

The first mixture was prepared without using any retardant admixtures and mentioned as the control mixture for the rest mixtures and symbolized by (CN0). The symbol (CN) indicated the mixture name and the number (0) indicated that it contained no retardant admixtures. The remaining nine mixtures which contained different retardant admixtures were classified into three groups, with three mixtures in each group. The first group of mixtures in which the three types of retardant admixtures were used only once at the beginning of the mixing process were symbolized by (AD1, BD1, and CD1). The symbol (AD) indicated the first admixture (Plastimnt -AR340) collected from Sika, the symbol (BD) refers to the second admixture (Addicrete BVSS) collected from CMB and the symbol (CD) refers to the third admixture (Techno-mix 130 CR) collected from (MTC) company. The number (1) designated that the three retardant admixtures were used only once in the mix and their addition time was at the start of mixing. The quantity of retardant admixtures used at the beginning of the mixing process according to mix design was 6.8 kg/m^3. The setting time of concrete for all mixtures of the first group and control mixture was determined before the preparation of the second and third group mixtures. The second group of mixtures whose symbols were (AD2M, BD2M, and CD2M) and the retardant admixtures were used twice, the first at the beginning of the mixing process and the second after some time equal to the middle of the initial setting time calculated using the penetration resistance device. Number (2) was added to the symbols of the mixtures of the second and third groups to indicate the use of the retardant admixtures two times during the preparation of samples.

The symbol (M) expresses the timing of the second additional dose being used after duration equal to the middle of the initial setting time which was measured beforehand.

The third group of mixtures whose symbols were (AD2H, BD2H, and CD2H) that retardant admixtures were used twice as well, the first at the beginning of the mixing process and the second at a period equal to half an hour before the pre-calculated initial setting time occurred. The symbol (H) indicated the timing of the second additional in the third group mixtures. The quantity of the additional dose of admixtures added for the second time was 1.7 kg/ 1m^3 which present 25% from the amount of admixtures used at the start of the mixing process. After the completion of the preparation of the mixtures of the third group, the time of setting was calculated for them in the same way for the first and second group's mixtures using the penetration resistance device. The workability test was determined and the compressive strength was examined for all samples used. The slump test was performed to evaluate the workability according to (ASTM C143, 2015). The slump test was performed for all mixtures used in the study at different times from the start of mixing and every an hour passed.

In accordance with the specifications, a 2000 kN compression machine was used to measure the compression of concrete cubes with a size of 150x150x 150 mm at 7 days, 28 days, 56 days, and 90 days of age. A series of three cubes was tested for every mix and the average rate of these three cubes was re-counted as a result. All cubes were cured with water before the test day.

Fig. 2. Penetration resistance test proceeding.

Table 3. Mix proportion details of ten mixes/1 m^3.

Mixes codes	Cement (kg)	Sand (kg)	Gravel (kg)	Water content (liter)	Admixture content (liter)	Admixture type	Number of using admixture in mixes
CN0	400	776	1154	160	--	--	--
AD1	400	776	1154	160	6.8	Plastimnt -AR340-Sika	1
BD1	400	776	1154	160	6.8	Addicrete BVSS-CMB	1
CD1	400	776	1154	160	6.8	Techno-mix 130 CR	1
AD2M	400	776	1154	160	8.5	Plastimnt -AR340-Sika	2
BD2M	400	776	1154	160	8.5	Addicrete BVSS-CMB	2
CD2M	400	776	1154	160	8.5	Techno-mix 130 CR	2
AD2H	400	776	1154	160	8.5	Plastimnt -AR340-Sika	2
BD2H	400	776	1154	160	8.5	Addicrete BVSS-CMB	2
CD2H	400	776	1154	160	8.5	Techno-mix 130 CR	2

4. Results and Discussions

4.1. Workability

The workability of all mixtures used in this study was assessed. The slump test was used to assess the workability of all mixtures. Table 4 presents the findings of slump value analysis for all used mixes. The slump was measured at the beginning of the mixing process and was re-measured at each passing hour.

Table 4 shows all workability measurement results for all mixtures using the slump test. The slump values for the control mixture (CN0) have decreased with the passage of time due to the occurrence of concrete hardening over time. The results showed that the use of retardant admixtures enhanced the workability by increasing the slump values for first-group mixtures containing retardant admixtures (AD1, BD1, and CD1) by average percentages of 14.3%, 7.7%, and 11.11%, respectively, relative to the reference mix (CN0) for the three types of admixtures used. This increment was due to the presence of retardant admixtures which slowed down the process of hardening concrete (Borahan et al., 2018). This result indicated that the mixtures continued to maintain a degree of workability due to the use of retarding admixtures at the beginning of casting. These results are consistent with what was obtained by Fernandes and Guptha (2021).

With respect to the second group of mixtures (AD2M, BD2M, and CD2M), the slump values varied with the use of retardant admixtures at the start of the mixing process and after the addition of the second dose at a time equal to the middle of the setting time of mixtures (AD1, BD1, and CD1). It was found that after 180 min from the start of the mixing process, the second group of mixtures recovered their ability to work and consistency, where the mixture slump values were 90 mm, 85 mm, and 80 mm, which was higher than the control mixture slump values after only one hour by 11.1%, 5.9%, and 12.5% respectively, as shown in Fig. 3. The slump values for the three mixtures were still suitable even after 300 min, allowing for casting, compaction, and leveling of concrete operations to be done without any hindrance. However, when using an additional dose of retardant admixtures at a time equal to the middle of the initial setting time, the concrete started to restore its workability again due to the availability of a liquid medium. Admixtures also worked, in addition to reducing friction between the concrete particles formed, which helped increase the slump values again.

Table 4. Slump values for all mixtures used.

Mixes codes	At 0 min (Batching)	After (60 min)	After (120 min)	After (180 min)	After (240 min)	After (300 min)
CN0	120	80	45	--	--	--
AD1	140	80	70	60	40	--
BD1	130	70	60	50	30	--
CD1	135	75	65	55	45	--
AD2M	160	120	85	90	75	55
BD2M	155	115	80	85	70	50
CD2M	150	110	75	80	60	45
AD2H	155	120	85	40	25	30
BD2H	150	110	80	35	22	25
CD2H	150	105	75	35	20	24

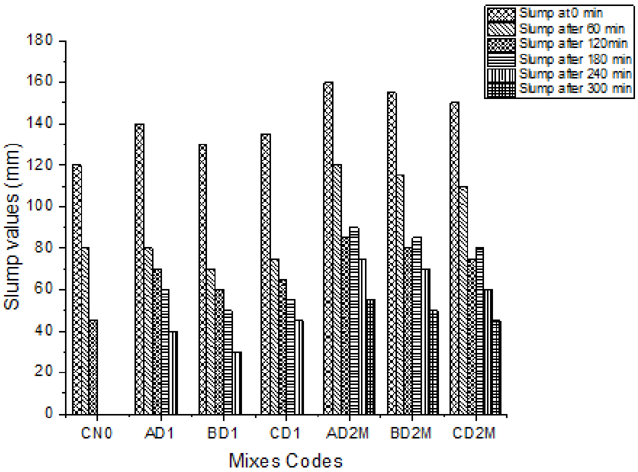

Fig. 3. Comparison between slump values of first and second groups mixtures with control mixture.

For the third group of mixtures (AD2H, BD2H, and CD2H), retardant admixtures were also used at batching, and then an additional second dose was used half an hour before the initial setting time occurred. The behavior of the mixtures did not cause a significant change, as with the passage of time, the slump values began to decrease because of the hardening of the concrete. Semi-temporary hardening of the hardening process occurred with the use of the second additional dose of admixtures half an hour before the initial setting time occurred, but it did not help to increase the concrete slump values and therefore did not improve the workability of the mixtures. Whereas after 300 min from the start of mixing, the values of slump of mixtures of the third group were 30, 25 and 24 mm, which was less than the values of slump of mixtures of the first group at the same time by 40%, 50% and 20%, respectively, as shown in Fig. 4. This result happened because most of the concrete particles lost their ability to form due to the passage of time and the occurrence of chemical reactions during the hardening process.

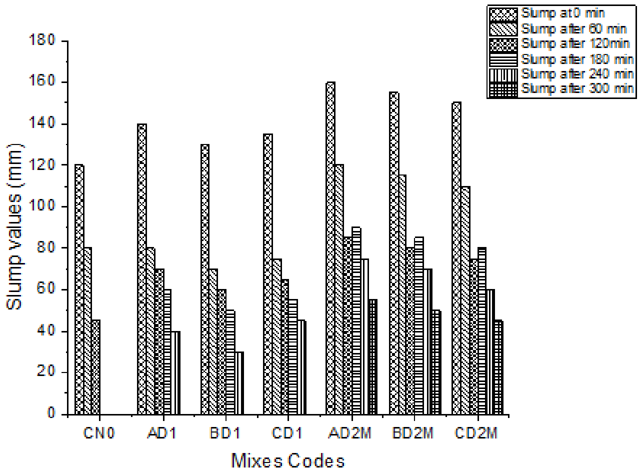

Fig. 4. Comparison between slump values of first and third groups mixtures with control mixture.

From these results, the positive influence of the additional dose of retardant admixtures was seen for a second time after a duration equal to the middle-term of the measured mixture-setting term of the first group (AD1, BD1, and CD1). This was because the use of the admixtures slowed down the occurrence of the hardening process for the first time when the mixture occurred. With the passage of time, the workability began to decrease, and with the addition of retardant admixtures again, the mixture recovered its workability according to the second addition, which facilitates the slipping of aggregates and cement granules. A liquid medium, which facilitated mixing and freedom of movement, was also given. With respect to the third group, in which the second additional dose was used half an hour before the initial setting time occurred, a continuation of declining slump values with the passage of time was observed and there was no noticeable increase in workability when the second addition of retardant admixtures was used, indicating that the hardening process had reached a stage that the mixtures could not handle. The second dose of admixtures at a time equal to half an hour before the initial setting time occurred did not help to slow down effectively, as was the case when the retardant admixtures were used at a time equal to the half-time of the calculated setting time for the mixtures used.

4.2. Setting time

In this study, the focus was on determining the setting time for concrete, since it was more important than estimating the setting time for cement. Because of the chemical reaction between cement components such as C3S and C3A with water, concrete setting occurs, and with the passing of time, the concrete becomes an increasing amount of hard and its surface resistance increases the strength of the penetrator arm. Table 5 displays the measurements of the initial and final setting time of all mixtures used. For mixes of the first group, the initial setting time was measured immediately after mixing and sample preparation. As a result, the setting time values for the control mixture using the penetration resistance apparatus have been found to be within their normal range. A significant difference in initial and final setting values occurred with the use of retardant admixtures in the first group of mixtures. The retardant admixtures delayed the initial setting time of the mixtures of the first group by 50%, 49%, and 48% compared to the initial setting time of the control mixture and delayed their final setting time by 34%, 31.96%, and 30.53% compared to the final setting time of the control mixture, as shown in Fig. 5. The presence of retardant admixtures slowed down the process of concrete hardening, allowing setting time to increase.

Table 5. Initial and the final setting time values for all mixtures by penetration resistance device.

Mixes codes	Initial setting time (min)	Final setting time (min)
CN0	130	330
AD1	260	500
BD1	255	485
CD1	250	475
AD2M	370	710
BD2M	360	690
CD2M	350	680
AD2H	300	560
BD2H	290	545
CD2H	285	540

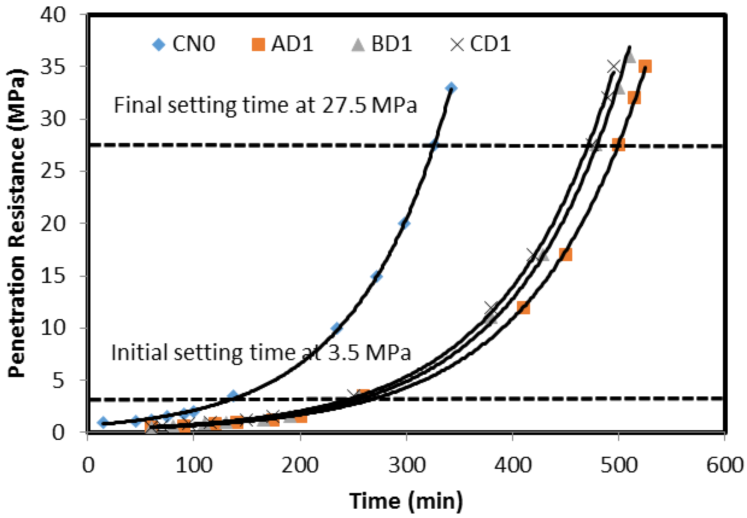

Fig. 5. Initial and the final setting time values for control mix and first group mixtures.

For mixtures of the second and third groups, the setting time was measured for them after adding the second dose of retardant admixtures according to the time of addition for each group. For the second group mixtures (AD2M, BD2M, and CD2M), the second addition was added after some time equal to the middle of the calculated initial setting time of mixtures (AD1, BD1, and CD1).With the addition of the second dose of retardant admixtures to the second group mixtures, their initial and final setting time delayed by 27.8%, 25%, and 24.2 compared to the initial setting time of the first group mixtures and delayed by 29.6%, 29.7%, and 30.1% compared to the final setting time of the first group mixtures, as shown in Fig. 6. The chemical reaction between the concrete components and the water began from the first moment of mixing; the continuous mixing of materials until the second dose of retardant admixtures was added helped to further reduce in the rate of concrete hardening. The act of retarder admixture delayed the direct hydration of C3A, decreasing the initial setting time (Belous et al., 2009). The timing of the second dose addition was also an important factor in increasing the setting time that helped to keep concrete in fresh condition. The use of a second extra dose of retardant admixtures in the middle of the setting time was appropriate to avoid strong bonding between concrete components, which helped to keep concrete in fresh condition for a while.

For the third group mixtures (AD2H, BD2H, and CD2H), the second addition was added at time equal to half an hour before the initial set of mixtures occurred based on the set time measured for the mixtures (AD1, BD1, and CD1).With the addition of the second dose of retardant admixtures to the third group mixtures, their initial and final setting time delayed by 13.3 %, 12.1% and 12.3 compared to initial setting time of the first group mixtures and delayed by 10.7%, 11% and 12% compared to the final setting time of the first group mixtures as shown in Fig. 7. As the general effect of retardant admixtures was to delay concrete hardening, the effect of adding the second dose of the mixtures to the mixes of the third group has continued, but with fewer rates. The results indicated that the timing of the addition of retardant admixtures half an hour before the initial set of concrete had slowed concrete hardening with fewer rates compared to the timing of the addition of the second dose of retardant admixtures after a time equal to the middle of the initial setting time. The reason for this was that the plasticity of fresh concrete had largely been lost over time and that it had not been able to recover the proper liquidity that helped to slow down the shape of concrete further. At this point, it was difficult for the concrete to absorb and interact with the admixtures, which showed that it did not have a clear effect on the slowdown of the hardening process.

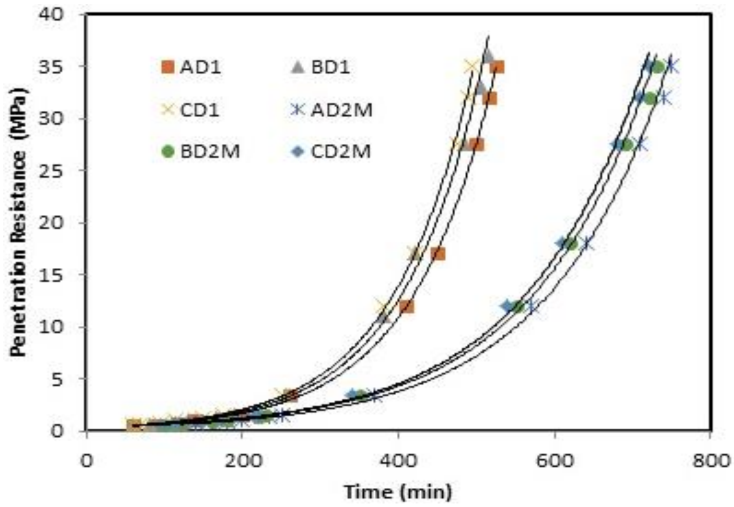

Fig. 6. Comparison between setting time values of first group mixtures and second group mixtures.

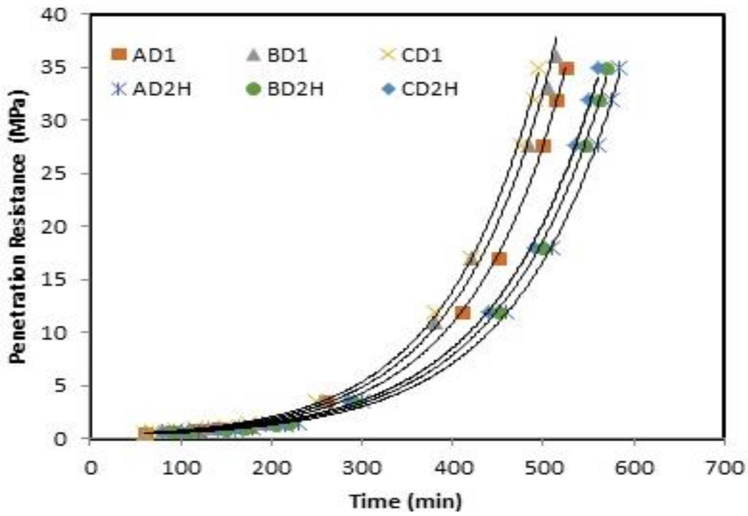

Fig. 7. Comparison between setting time values of first group mixtures and third group mixtures.

4.3. Compressive strength

Table 6 shows the compressive strength values for all samples tested at ages 7, 28, 56 and 90 days. The results illustrated a significant increase in compressive strength of the mixtures in which the retardant admixtures were used at the start of blending and at all ages for the three types of admixtures used.

Table 6. Compressive strength values for all mixtures used.

Mixes codes	Compressive Strength(MPa)			
	7 days	28 days	56 days	90 days
CN0	28	33	40	46
AD1	32	38	45	52
AD2M	29	34	39	44
AD2H	26	30	32	35
BD1	31	37	44	50
BD2M	28	33	39	43
BD2H	25	29	31	34
CD1	30	36	43	50
CD2M	27	32	38	43
CD2H	24	28	31	34

The compressive strength of all mixtures of the first group in which the retardant admixtures were used at the start of mixing exceeded the compressive strength of the control mixture at all ages. The average percentages of increasing in compressive strength were 9.7% at 7 days, 10.8% at 28 days, 9.1% at 56 days and 9.3% at 90 days than control mixture. This was due to the fact that the admixtures increased the interaction and movement of cement particles that were non-reactive at all ages (Alsadey, 2013).

Fig. 8 shows the compressive strength values for mixtures that contained first retardant admixture (AD) at different ages by displaying values at each age. It was found that the value of compressive strength increased when using the admixture (AD) at the beginning of mixing, as it improved the workability quality of the mixture, which helped to increase the compressive strength of the mixture, while when using the retardant admixture for the second time as an additional dose after the middle of the initial setting time had passed, the compressive strength value of the mixture AD2M decreased by 10.5% compared to the mixture (AD1) at 28 days of age, but its value was still higher than the compressive strength of the control mixture (CN0) by 3% at the same age.

This was because, with the passage of time, from the beginning of the mixing to the middle of the initial set time, concrete began to harden, the workability of the mixture was reduced, which was a major reason for the low compressive strength value.

When a second addition of retardant admixture was used at half an hour before the initial setting time of mixture (AD2H) occurred, it was found that compressive strength of mixture (AD2H) decreased by 21% compared to the compressive strength of mixture (AD1) and decreased by 9% compared to the compressive strength of the control mixture (CN0). It was because concrete matrix had set part of it and thus decreased rates of workability, which helped to minimize compressive strength.

The rate of increasing compressive strength for both mixtures (AD1) and (AD2M) was in the usual range for late ages (56 days and 90 days). The rate of increasing compressive strength for the mixture (AD2H) over time was sluggish, as the compressive strength value for it reached 32 N/mm^2 at the age of 56 days, which was expected to reach it at 28 days. This indicated that the second use of retardant admixture half an hour before the initial assumption occurred had a damaging impact because it served to decrease concrete strength.

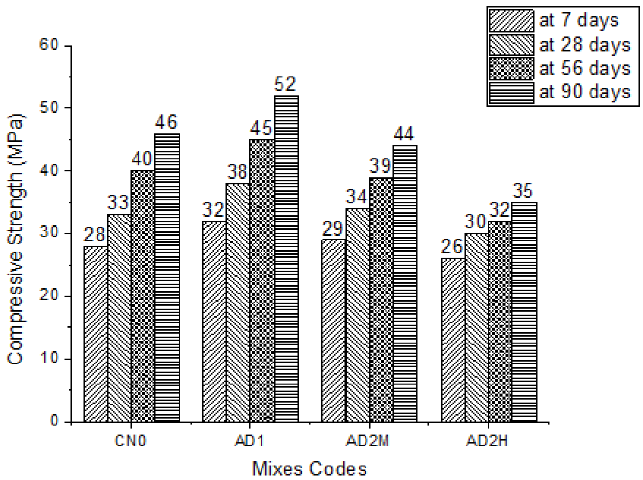

Fig. 8. Compressive strength values of first admixture mixtures (AD) comparing with compressive strength of control mixture (CN0).

Fig. 9 displays a comparison between the compressive strength value of the control mixture (CN0) at different ages and the compressive strength values when using the second admixtures (BD), whether at the start of mixing or at the middle of the calculated initial setting time or half an hour before the initial setting time has been occurred. In the presence of the retardant admixture (BD1) at the start of batching, the compressive strength increased in all ages. The rise in compressive strength was 9.7%, 10.8%, 9%, 8% respectively at 7, 28, 56, 90 days compared to control the mixture (CN0). The compressive strength value of the mixture (BD2M) decreased by 10.8% compared to the mixture (BD1) at the age of 28 days. This was because when the retardant admixture was added for the second time in the middle of the initial setting time, it caused a delay in time that worked to allow a partial set for some concrete particles to occur. This operation helped to slow down the reaction process between water and cement particles. The slower the reaction, the lower the bonding force between the concrete particles, which reduced the compressive strength. However, it did not prohibit the maintenance of an installation, even though it was simple compressive strength, to prohibit its configuration, which could lead to disposal in the case of an emergency at the site, because the compressive strength of the mixture was still greater than the compressive strength of the control mix.

It is also clear from the figure that the compressive strength decreased by 21.6% compared to the compressive strength of (BD1) at 28 days of age when using the second dose of the mixture half an hour before the occurrence of the initial setting time which calculated in advance by the mixture penetration resistance (BD2H). This was because the reaction happened as soon as the water reached the cement granules and concrete bonds started to form, and when the admixture was used the hardening phase slowed down and the mixing state was insignificant currently, thus reduced the compressive strength. The compressive strength trend for the second admixture (BD1) at later ages was similar to the first admixture (AD1).

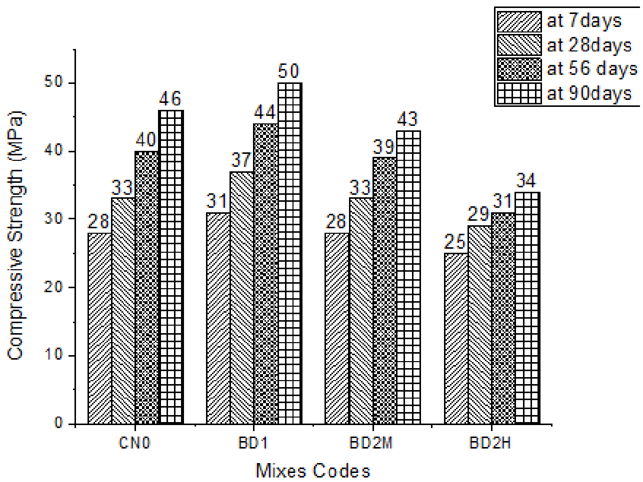

Fig. 9. Compressive strength values of second admixture mixtures (BD) comparing with compressive strength of control mixture (CN0).

Fig. 10 shows the compressive strength values for the third admixture (CD) at different ages 7, 28, 56, and 90 days and as a relationship with the compressive strength of control mixture at the same age. The compressive strength of mixture (CD1) in which the retardant admixtures were used at the start of mixing exceeded the compressive strength of the control mixture at all ages, increasing by 6.7% at 7 days, 8.3% at 28 days,7% at 56 days and 8% at 90 days. As happened with the first and second admixtures, it was found that the values of the compressive strength when using the retardant admixture during mixing process exceeded the values of compressive strength of concrete, as well as for an improvement in workability, which helped in improving compaction, which helped increase the strength of concrete.

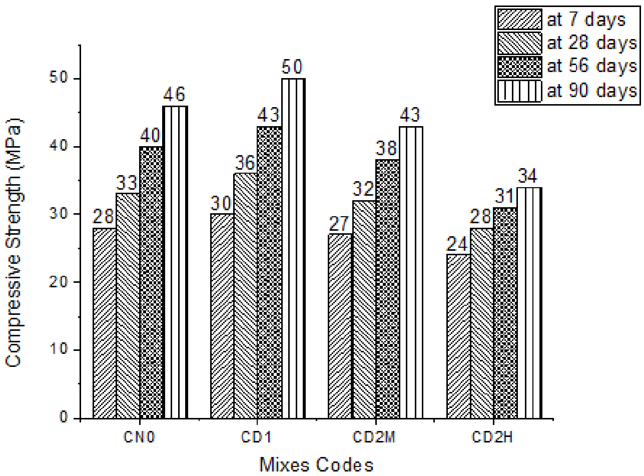

Fig. 10. Compressive strength values of third admixture mixtures (CD) comparing with compressive strength of control mixture (CN0).

In terms of the value of the resistance to compressive strength when using a second dose of admixture, the compressive strength from as it was at the start of mixing by 10% at 7 days, 11.1% at 28 days, 11.6% at 56 days and 14% at 90 days. This was due to a change in the strength of concrete, where the second addition slowed the completion of the reaction process between water with cement, which slowed hardening process. From the homogeneity of the admixture, which helped in the absence of good cohesion between the particles, and that the medium became inconsistent, and the difference between the hardening rate and its incompatibility might also be a factor in reducing compressive strength. However, the compressive strength values for this mixture (CD2M) were still higher than the compressive strength values for the control mixture (CN0); the compressive strength of the mixture was still good and appropriate given the increased initial setting time more because of the use of retardant admixture. When the second dose of the retardant admixture was used half an hour before the initial setting of the mixture was done, the compressive strength values for the mixture (CD2H) were lower than the compressive strength values of the control mixture (CN0) by 20% at 7 days, 22.2% at 28 days, 28% at 56 days and 32% at 90. That was to say, the use of retardant admixture at this period helped loosen the bonds between the concrete particles after they started to consolidate and interconnect which helped mixtures to multiply over time and was the explanation for their low compressive strength.

5. Conclusions

This paper investigates the effect of three types of retarding admixtures on the performance of concrete. The study concluded that:

- The use of an additional second dose of retardant admixtures after a time equivalent to the middle of the initial setting time helped concrete to recover its workability which facilitates the slipping of aggregates and cement granules. Slump values were increased again due to the use of an additional dose of retardant admixtures.
- The second additional dose of retarding admixtures not only delayed the concrete setting but also was effective for concrete compressive strength.
- The use of an additional second dose of the retardant admixtures after a time equivalent to the middle of the initial setting time has yielded acceptable results for the concrete properties in forms of workability and compressive strength. However, the use of the additional second dose half an hour before the initial setting time occurred has not significantly effect on concrete properties.
- The first admixture (AD) gave results better than the other two types used in this study for the properties of concrete in terms of workability, setting time and compressive strength.
- The use of an additional dose of retardant admixtures is an important option for preventing the return of ready-mixed fresh concrete and postponing casting without harmful effects by keeping the concrete in a fresh condition more than 5 h.

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