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THE EFFECTS OF ACCELERATER AND RETARDER CHEMICAL ADMIXTURES ON CONCRETE SETTING TIME

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Abstract

In this study, the effects of chemical admixtures which are accelerators and retarders on concrete setting time were investigated. For this purpose, concrete mix having constant slump and dosage has been designed. 0,5%, 1%, 1,5% and 2% setting accelerator and retarder chemical admixtures by cement quantity have been supplemented in the mixtures. Totally 9 batch, a set of control mix and 8 different concrete mixes having chemical admixtures, have been prepared. Slump and Ve-Be experiments were tested in order to determine workability of the fresh concrete. The setting times which are come up to 0,5MPa, 1MPa ve 3 MPa strengths have been determined using penetration method. The obtained test results were evaluated by using statistical methods. As a results, it is seen that the accelerators was reduced the concrete workability, retarders was enhanced the concrete workability, the setting time of the concrete was increased 21% and 12% with using accelerator and retarder respectively.

Keywords: Accelerators, Retarders, Setting Time, Concrete, Chemical Admixtures

1. Introduction

Cement paste which is prepared with cement and water hardens in process of time and is formed by setting. Hardening of cement is called set. Setting of cement and concrete is occurred due to chemical reactions between cement paste and water. Normal set of cement is formed by C3S (Alite) through composing of hydration and gel of calcium silica hydride. By reaching the initial setting time, the process of compacting and smoothing the surface of concrete becomes difficult. In case, reaching to the final setting time cement paste completely sets and gains strength [3, 4, 5].

In order to determine the setting time of fresh concrete, different methods of experiment which are based on measuring the changes in concrete consistency, wave velocity of vibration sent to concrete, sweating, heat change in hydration, change in volume and strength of concrete against penetration are generally used. The method of measuring the strength of fresh concrete against penetration is broadly accepted among the other different methods of experiment to determine the setting time of concrete [6, 7].

Chemical admixtures cause rheological changes in mixture of fresh concrete. Chemical admixtures are two types as accelerators and retarders. The effects of chemical admixtures on concrete can be explained by dissolving of waterless components which is consisted of anion (silica and aluminate) cation (calcium). The function of accelerators in cement is to control the dissolution of anion and cation and whereas the function of retarders is to prevent the dissolution of cations in cement [8, 9, 10].

Main components of accelerators are calcium nitrate and nitrite, thiosulphate, phormates and triethanolamines. Accelerators shorten the setting time, raise the early age strength and increase the heat of hydration in early hours. On the other hand, accelerators have some disadvantages like loss of workability, rise of shrinkage, decrease in final strength and increase of alkali aggregate reactivity. Main components of retarders are gluconate, salicylic acid, calcium lignosulfate and sodium boroheptonates. Retarders extend the setting time, increase the final concrete strength in small amount and decrease the amount of water in mixture. However, retarders have some disadvantages like decreasing early age strength, increasing hydraulic

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shrinkage, depending on temperature and quantity excessively in main function.

The process of conveyance, placing, compacting and smoothing the surface which are going to be applied to fresh concrete are carried out before the concrete sets. Situations such as the distance between the place of production and usage area, seasonal requirements etc., ascertain the importance of setting time. Thus, determining the setting time of concrete has importance. In this study, the setting times of samples which have been acquired by using %0,5 , % 1, %1,5 , %2 setting accelerators and retarder chemical admixtures of cement quantity in concrete have been determined by the method of penetration strength.

2. MATERIAL AND METHOD

2.1 Material

In this study, aggregate which has been obtained from Düzce Melen River and crushed into three different dimensions has been used. The biggest grain size of aggregate mixture quantity is selected as 31,5 mm. Aggregates have been adjusted, according to limited values in TS 706 (5) as %20 natural sand, %30 0-5 mm broken stone, %25 5-15 mm broken stone and % 25 15-25 mm broken stone. Results of sieve analysis of used aggregates are given Table 1 and the results of specific weight, water absorption and loose unit weight experiments are given in Table 2.

Table 1. Aggregate Sieve Analysis

	Class of aggregate	**Sieve Size (mm)**							
		31,5	**16**	**8**	**4**	**2**	**1**	**0,5**	**0,25**
Passing the Sieve (%)	Natural Sand	100	100	100	100	74	58	44	21.6
	0-5 Crushed Sand	100	100	100	99	74	59	38	11.0
	5-15 Crushed Stone	100	100	86	14	0.3	0.2	0.1	0
	15-25 Crushed Stone	100	62	0.5	0.1	0	0	0	0

Table 2. The values of specific weight, water absorption and loose unit weight of used aggregate

Aggregate Type	**Specific Weight (kg/m^3)**	**Water Absorption (%)**	**Loose Unit Weight (kg/m^3)**
Natural Sand	2710	1.2	1610
0-5 Crushed Sand	2700	0.9	1490
1 no Crushed Stone	2720	0.9	1410
2 noCrushed Stone	2730	0.6	1480

In experimental study, CEM I 42, 5 R type of cement has been used. As a chemical admixture accelerators and retarders which have been supplied from Chryso Company have been used. Technical features of accelerators and retarders are given in Table 3.

Table 3. Technical features of accelerators and retarders admixtures

Accelerator		**Retarders**	
Appearance	Liquid	Appearance	Liquid
Colour	Viole	Colour	Brown
Total Solid	32,5 $^{-}_{+}$ 2	Freezing point	-1 ^{0}C
Density (gr/cm^3)	1,31	Density (gr/cm^3)	1,070
Chloride Content	%0,1	Chloride content	Not contain
pH	11	pH	5,5

2.2 Method

In the study, class of C20 has been selected as target strength in preparing concrete samples. As a result of pre-experiments, it has been decided that proportion of Water/Cement (W/C) is 0.60 in mixtures. Design of concrete mixture has been done according to TS 802. In concrete mixture, the quantities of Cement/Water/Gravel/Sand have been selected in order of 300/180/842/1028 kg/m3. In concretes which have been produced with accelerators and retarders, the quantities of admixtures have been selected in order of 0.5%, 1%, 1.5% and 2% according to cement weight. Admixtures have been adjoined to concrete compound by adding into mixture water. 9 different batch containing accelerators –retarders chemical admixtures reference to 0.5%, 1%, 1.5% and 2% have been prepared

2.2.1 Slump and Ve-be Experiment

In accordance with TS EN 12350-2 and TS EN 12350-3 standards, slump and Ve-be experiments have been applied to 9 different fresh concrete mixture which have been prepared **to** determine the effects of accelerators and retarders on fresh concrete workability [13, 14].

2.2.2 Determining Setting Times

In order to determine penetration strength, three prepared concrete samples from each batch which have been applied slump and ve-be experiments have been poured into 15x15x15 cm forms after the process of sieving in 4 mm mesh. For the purpose of determining setting time, the method of measuring the resistance of fresh concrete against penetration, which is one of the well accepted method among the other experimental methods, have been used.

Determining the setting time have been made according to TS 2987 (ASTM C 403) by measuring the resistance of concrete mixture against penetration [15, 16]. On prepared fresh concrete mortar, the setting times have been determined until coming up to 0.5 MPa, 2 MPa, and 3 MPa strength by the help of penetration instrument with probe tip having ¼ inch^2=161,29 mm^2 area. After fresh concrete has been placed, measurements related to setting times have been noted by penetration instrument as shown in Figure 1.

Figure 1. Penetration application to fresh concrete mortar

3. Results and Discussion

3.1 Slump and ve-be values

The descriptive statistics of slump and Ve-be (sn) experiment results which have been carried out in order to determine fresh concrete workability throughout prepared samples, are given in Table 4. Also, the graphics of slump and Ve-be experiment results are seen in Figure 2.

Table 4. Statics of Mixtures with accelerators and retarders

Type of Chem. Adm	Admix Quant (%)	N	Average Slump / Ve-be	Std.	%95 Confidence Interval Average		Min.	Max.
					Min Limit	Max. Limit		
Accelerator Slump (cm)	0	3	7.83	0.17	7.12	8.55	8	8
	0.5	3	20.83	0.44	18.94	22.73	20	22
	1.0	3	18.50	0.29	17.26	19.74	18	19
	1.5	3	15.67	0.33	14.23	17.10	15	16
	2.0	3	15.50	0.29	14.26	16.74	15	16
Accelerator Ve-Be (sec)	0	3	7.33	0.17	6.62	8.05	7	8
	0.5	3	5.50	0.29	4.26	6.74	5	6
	1.0	3	7.17	0.17	6.45	7.88	7	8
	1.5	3	7.67	0.33	6.23	9.10	7	8
	2.0	3	8.17	0.17	7.45	8.88	8	9
Retarder Slump (cm)	0	3	7.67	0.33	6.23	9.10	7	8
	0.5	3	15.67	0.33	14.23	17.10	15	16
	1.0	3	18.67	0.33	17.23	20.10	18	19
	1.5	3	21.33	0.33	19.90	22.77	21	22
	2.0	3	24.67	0.33	23.23	26.10	24	25
Retarder Ve-Be (sec)	0	3	6.83	0.44	4.94	8.73	6	8
	0.5	3	6.33	0.33	4.90	7.77	6	7
	1.0	3	5.50	0.29	4.26	6.74	5	6
	1.5	3	4.50	0.29	3.26	5.74	4	5
	2.0	3	3.17	0.17	2.45	3.88	3	4

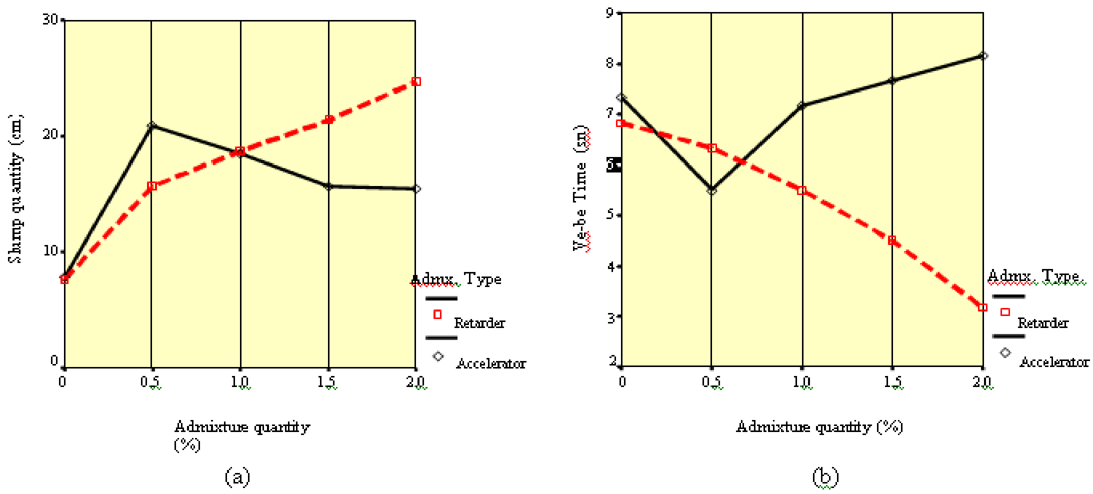

Figure 2. The values of slump (a) ve Ve-be (b) in admixtures of accelerator and retarder

In each admixture type, variance analysis has been carried out between groups in order to determine the effects of accelerator and retarder admixtures on concrete workability as a result of experiment (Table 5). It has been seen that the quantity of accelerators and retarders change the slump and Ve-be values of fresh concrete significantly as a result of variance analysis. The results of Duncan multiple comparison test which has been carried out between admixture quantities are given in Table 6.

Table 5. Result of variance analysis of accelerated and retardered mixtures

Chemical Admx Type	Variance Source	Total of Square	Degree of Freedom	Average of Square	F-Test	Signficance Level $p \leq 0,05$
Accelerator Slump	Among Groups	288,333	4	72,083	240,278	0,000
	In Groups	3,000	10	0,300		
	Total	291,333	14			
Accelerator Ve-Be	Among Groups	12,167	4	3,042	18,250	0,000
	In Groups	1,667	10	0,167		
	Total	13,833	14			
Retarder Slump	Among Groups	502,267	4	125,567	376,700	0,000
	In Groups	3,333	10	0,333		
	Total	505,600	14			
Retarder Ve-Be	Among Groups	25,933	4	6,483	21,611	0,000
	In Groups	3,000	10	0,300		
	Total	28,933	14			

According to multiple comparison test;

- It has been observed that there is a little increase by usage of %0.5 accelerator. Whereas there are decreases in workability by usage of %1. %1.5. %2 due to the decrease in concrete setting time.
- The lowest workability values have occurred in unmixed concrete whereas the highest workability has occurred in admixtured concrete by %0.5 accelerator.
- By usage of %0.5 accelerator. Slump values have shown %62 increase whereas Ve-be values shown %33 decrease.
- It has been observed that concrete workability increases correspondingly to the increase of retarder usage.
- It has been ascertained that there is %69 increase in slump values by usage of %2 retarder whereas there is %54 decrease in Ve-be values.

Table 6. Results of multiple comparison test of accelerator and retarder mixtures

Chemical admix Type	Admix Quantity (%)	N	Different Groups ($p \leq 0.05$) 1	2	3	4	5
Accelerator Slump	0	3	7.83				
	2.0	3		15.50			
	1.5	3		15.67			
	1.0	3			18.50		
	0.5	3				20.83	
Accelerator Ve-Be	0.5	3	5.50				
	1.0	3		7.17			
	0	3		7.33			
	1.5	3		7.67	7.67		
	2.0	3			8.17		
Retarder Slump	0	3	7.67				
	0.5	3		15.67			
	1.0	3			18.67		
	1.5	3				21.33	
	2.0	3					24.67
Retarder Ve-Be	2.0	3	3.17				
	1.5	3		4.50			
	1.0	3			5.50		
	0.5	3			6.33	6.33	
	0	3				6.83	

3.2 Concrete Setting Times

The statics of concrete setting times which have been determined by the method of penetration on accelerated concrete mixtures are given in Table 7. Besides the graphics of average concrete setting times in accelerated mixtures are seen in Figure 3.

Table 7. Statics of setting times in accelerated concrete mixtures

Penetration Strength (MPa)	Accelerator Admix Quantity (%)	Average Setting Time (dak)	Std. Dv	%95 Confidence Interval Average		Min.	Max.
				Min Limit	Max. Limit		
0.5	0	241.3333	2.33333	231.2938	251.3729	237.00	245.00
	0.5	220.2200	4.09930	202.5821	237.8579	213.15	227.35
	1.0	198.6267	8.74733	160.9900	236.2634	181.46	210.13
	1.5	184.5200	2.45090	173.9746	195.0654	180.29	188.78
	2.0	177.2167	4.54331	157.6684	196.7649	168.29	183.15
1	0	276.3333	3.48010	261.3597	291.3070	270.00	282.00
	0.5	254.1167	7.36443	222.4301	285.8033	240.73	266.13
	1.0	230.5300	2.22264	220.9667	240.0933	227.35	234.81
	1.5	226.3733	2.14493	217.1444	235.6022	223.27	230.49
	2.0	210.3567	3.84817	193.7993	226.9140	203.66	216.99
3	0	392.3333	2.18581	382.9285	401.7381	388.00	395.00
	0.5	381.2633	1.08613	376.5901	385.9366	379.30	383.05
	1.0	357.4567	1.76892	349.8456	365.0677	355.34	360.97
	1.5	317.4600	.87069	313.7137	321.2063	315.87	318.87
	2.0	312.0300	1.31465	306.3735	317.6865	309.90	314.43

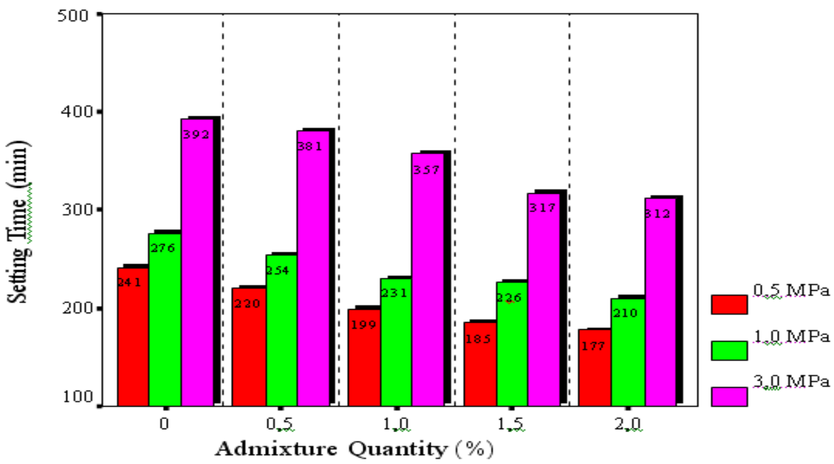

Figure 3. Average setting time in accelerated mixtures

As a result of the experiments variance analysis has been carried out between admixture quantities for the purpose of determining the effects of accelerator admixture quantity on concrete setting times (Table 8). As a result of variance analysis. It has been observed that the quantity of accelerator changes the concrete setting time significantly. Results of Duncan multiple comparison test between admixture quantities are given in Table 9.

Table 8. Result of variance analysis in accelerated admixture concretes

Variance Source	**Square Total**	**Degree of Freedom**	**Squrae Averages**	**F Test**	**Significance Level (p≤0.05)**
Among Groups	15910.347	4	3977.587	572.829	0.000
In Groups	69.438	10	6.944	-	-
Total	15979.785	14	-	-	-

Table 9. Results of Duncan multiple comparison test in accelerated admixture concretes

Admixture Quantity(%)	**N**	**Different Groups (p≤0.05)**				
		1	**2**	**3**	**4**	**5**
2.0	3	312.0300	-	-	-	-
1.5	3	-	317.4600	-	-	-
1.0	3	-	-	357.4567	-	-
0.5	3	-	-	-	381.2633	-
0	3	-	-	-	-	392.3333

According to multiple comparison test results;

- Concrete setting time shortens when accelerator admixture quantity increases
- Setting times in different admixture quantity of concrete differ from each other in statistical sense.
- Increase in admixture quantity causes decrease in setting time significantly
- The lowest setting time is 312.03 min. by %2 usage of admixture. whereas the highest setting time is 392.33 min. in unmixed concrete.

It has been seen that %2 usage of accelerator admixture decreases the setting time %21 compared to unmixed concrete.

The statics of concrete setting time which have been determined by method of penetration on accelerated concrete mixture are given in Table 10. Also the average concrete setting times in accelerated mixtures are seen in Figure 4.

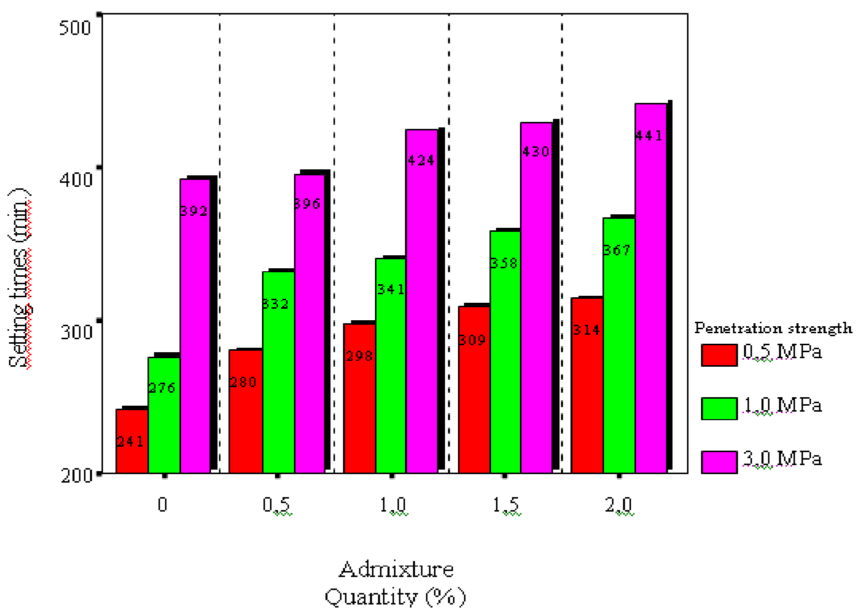

Figure 4. Average setting time in accelerated mixtures

Table 10. Statics of setting times in retarted concrete mixtures

Penetration Strength (MPa)	Accelerator Admix Quantity (%)	Average Setting Time (dak)	Std. Dv	%95 Confidence Interval Average Min Limit	Max Limit	Min.	Max.
0.5	0	241.3333	2.33333	231.2938	251.3729	237.00	245.00
	0.5	279.7567	2.46696	269.1422	290.3711	275.00	283.27
	1.0	297.8167	2.40835	287.4544	308.1790	293.00	300.24
	1.5	308.6667	1.76383	301.0775	316.2558	306.00	312.00
	2.0	314.0000	1.52753	307.4276	320.5724	312.00	317.00
1	0	276.3333	3.48010	261.3597	291.3070	270.00	282.00
	0.5	331.5900	2.42467	321.1575	342.0225	327.00	335.24
	1.0	341.0000	1.52753	334.4276	347.5724	338.00	343.00
	1.5	358.0000	1.52753	351.4276	364.5724	355.00	360.00
	2.0	366.6667	1.85592	358.6813	374.6521	363.00	369.00
3	0	392.3333	2.18581	382.9285	401.7381	388.00	395.00
	0.5	396.0000	1.15470	391.0317	400.9683	394.00	398.00
	1.0	424.2433	1.84911	416.2873	432.1994	420.73	427.00
	1.5	430.0000	1.00000	425.6973	434.3027	428.00	431.00
	2.0	441.3333	1.20185	436.1622	446.5045	439.00	443.00

Variance analysis has been carried out among admixture quantities for the purpose of determining the effects of retarder admixture quantity on concrete setting time. As a result of variance analysis, statistical difference among groups has been observed. In other words, concrete setting times change significantly depending on the quantity of retarder admixture. The results of Duncan multiple comparison test which has been carried out among admixture quantities in order to determine the groups which cause difference are given in Table 11.

Table 11. Results of Variance Analyses of Retarder Entrained Mixes

Variance Resource	Sum of Squares	Degree of Relief	Average Of Squares	F Test	Significance Level (p≤0.05)
Between Groups	5588.351	4	1397.088	194.449	0.000
In Groups	71.849	10	7.185	-	-
Total	5660.200	14	-	-	-

Table 12. Test Results of Duncan's Multiple Comparisons of Retarder Entrained Mixes

Admixture Quantity (%)	N	Different Groups (p≤0.05) 1	2	3	4
0	3	392.3333	-	-	-
0.5	3	396.0000	-	-	-
1.0	3	-	424.2433	-	-
1.5	3	-	-	430.0000	-
2.0	3	-	-	-	441.3333

According to results of multiple comparison test;

- Concrete setting time extends when the quantity of retarder admixture increases.
- There is no statistical difference in concrete setting times between unmixed concretes and concretes by %0.5 retarder admixture.
- The other admixture quantities are different from each other significantly.
- Increase in admixture quantity causes significant increase in setting times
- The lowest setting time is 392.33 min. in unmixed concretes whereas the highest setting time is 441.33

min by %2 usage of retarder admixture

- It has been observed that %2 usage of retarder admixture increase the setting time %12 compared to unmixed concrete.

Regression analysis has been carried out for the purpose of determining the relationship between penetration strength and concrete setting times in different admixture proportions of both admixtures. As a result of regression analysis; It has been observed that there is a strong relationship between penetration strength and concrete setting times and this relationship can be explained by Y=a+b X linear equation. Model equations, correlations and regression modulus which have been obtained as a result of regression analysis are given in Table 13. Accordingly, strong relationship between penetration strength and concrete setting time has been ascertained. This relationship is explained by high regression modulus such as r^2 =0.92 – 0.99. Besides the graphics which show the relationship between chemical admixture quantity for concretes with accelerator and retarder and concrete setting times depending on penetration strength are given in Figure 5.

Table 13. The results of regression analysis of both chemical admixtures

Chemical Admixture Type	**Admixture Quantity (%)**	**Correlation Coefficient (R)**	**Regression Coefficient) (R^2)**	**Model Equation (Y=a+b.X)**
	0	0.998	0.995	Y=213.762+59.714.X
	0.5	0.962	0.925	Y=272.162+42.414.X
Retarder	1	0.987	0.974	Y=282.333+48.014.X
	1.5	0.974	0.948	Y=298.127+44.952.X
	2	0.972	0.945	Y=303.429+47.048.X
	0	0.998	0.995	Y=213.762+59.714.X
	0.5	0.995	0.990	Y=188.936+64.176.X
Accelerator	1	0.994	0.988	Y=166.936+63.512.X
	1.5	0.991	0.983	Y=166.292+50.995.X
	2	0.995	0.990	Y=153.637+53.043.X

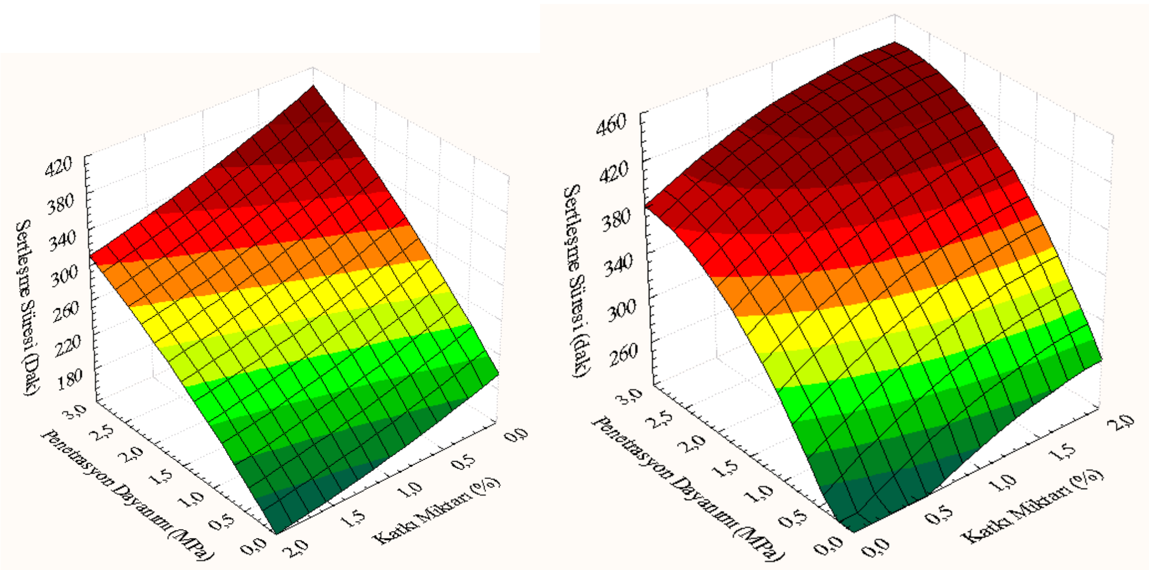

Figure 5**.** Graphic of relationship of accelerated (a) and retarder (b) admixture

4. Conclusion

Concrete setting time experiments of samples have been carried out by using %0.5. %1. %1.5 and /%2 setting accelerator and retarder chemical admixtures by cement quantity in the concrete mixture with fixed proportion by the slump. ve-be and penetration methods. Fresh concrete's setting times which came up to 0.5MPa. 1MPa and 3MPa strengths have been determined.

As a result of the evaluations on the experiment datas. It is seen that the amount of the accelerator and the retarders can change the fresh concrete's slump and ve-be accounts significantly and there are decreases in concrete workability by usage of accelerator whereas there are increases in concrete workability by usage of retarderadmixture.

It has been determined that by the usage of accelerator concrete setting time has changed significantly. The more accelerator amount makes the concrete setting time shorter and by the usage of %2 accelerator admixture the concrete setting time decreases %21. On the other hand it has been seen that dependingly on the amount of retarder admixture concrete setting time changes significantly. the more amount retarder admixture makes the concrete setting time longer and by the usage of %2 amount of retarder admixture the concrete setting time increases %12. Furthermore, it has been ascertained that there is a powerful relationship between different admixture amounts of penetration strengths in different admixture types and concrete setting times and this relationship can be implied by lateral linear equation.

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