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THE PERFORMANCE OF SILICA FUME ADMIXTURED CONCRETE UNDER THE EFFECT OF AMMONIUM SULFATE

ABSTRACT

In this study, it has been used 2% ammonium sulfate $(NH_4)_2SO_4$ solution thought that make the concrete corrosive effect to the concrete. Under this effect, it has been tried to determine that 10% substituted silica fume against pure concrete. Finally, samples that added silica fume on an average 18.29% have more compression strength than pure samples. There hasn't been any significant length change in the samples, while the concrete samples which added silica fume have shown 0.541% less weight change.

Keywords: Ammonium Sulfate, Silica Fume, Strength, Durability

SİLİS DUMANLI KATKILI BETONUN AMONYUM SÜLFAT ETKİSİ ALTINDAKİ PERFORMANSI

ÖZET

Bu çalışmada, betona korozif etki yapacağı düşünülen %2lik amonyum sülfat $(NH_4)_2SO_4$ çözeltisi kullanılmıştır. Bu etki altında %10 silis dumanı ikameli betonun katkısız betona göre performansı belirlenmeye çalışılmıştır. Sonuç olarak silis dumanlı numuneler katkısız numunelere göre ortalama %18,29 fazla basınç dayanımı göstermiştir. Önemli bir boy değişimi gözlenmezken, silis dumanlı numuneler katkısız numunelere göre ortalama %0,541 daha az ağırlık değişimi göstermiştir.

Anahtar Kelimeler: Amonyum Sülfat, Silis Dumanı, Dayanım, Dayanıklılık

1. INTRODUCTION (GİRİŞ)

Concrete is a composite structural material that conventionally consists of aggregates, cement and water. In recent years, in addition to the usage of some chemical admixtures, several different mineral admixtures are used with the conventional components of concrete. Chemical admixtures are used to enhance the properties of fresh and hardened concrete, whereas mineral admixtures are used to increase the physical and chemical durability properties of concrete under bad environmental conditions.

Silica fume is an artificial pozzolanic material that is obtained as a by-product in the production of silicon metal and ferrosilicon alloys that are used in semi-conductor industry. It contains approximately 90% silicon dioxide and its specific weight is about 2.20 kg/lt [1].

Waters and soils containing free acids, sulfides, sulfates, ammonium nitrates, magnesium nitrates, and some organic compounds have harmful effects on concrete [2].

Destructive effects of chemical substances on concrete may be of several different ways. Acids react with calcium hydroxide and form salts soluble in water. These salts segregate from concrete causing an increase in the permeability of concrete and a decrease in the resistance of concrete against harmful effects. Sulfates depending on the cation form gypsum or etrengit and cause expansions and cracks in the concrete or segregate C-S-H gel. The role of C_3A content in cement in most of these destructive reactions is important.

$$CH + S + H \longrightarrow CSH \quad (1)$$

C-S-H compound that forms at the end of the upper reaction has binding properties so that it increases the strength of cement paste. But the speed of this reaction is very low. Therefore, pozzolanic concretes gain their strength slowly [3].

It is observed that with the addition of silica fume 10-30% by weight of cement the resistance of mortars to sodium, magnesium and calcium chlorides increases significantly [4]. With the addition of 10-15% silica fume to the normal portland cement, cement similar to the sulfate resistant cement (ASTM Type V) is obtained. Particularly, silica fume addition is effective against sodium sulfate [5]. On the other hand, silica fume addition in general has adverse effects against magnesium sulfate. This phenomenon is explained by the transformation of the pozzolanic C-S-H gel to the hydrate magnesium hydroxide (M-S-H) gel which doesn't have binding properties and by the reduction of magnesium hydroxide (MH) layer which helps the mentioned reaction [6].

There is experimental evidence that silica fume addition has positive effects on the resistance of mortars against ammonium sulfate [7]. Ammonium salts except from ammonium carbonate, ammonium oxalate and ammonium fluoride, mainly effect the calcium hydroxide in hardened cement paste and segregate it from the paste [2].

According to Huang and Feldman, silica fume produces more CH by catalyzing hidratation at the first 8 hours; however it successively enables CH to be bound. It is observed that by adding 10-30% silica fume by weight of cement, the resistance of mortars against magnesium and calcium chlorides increases significantly [4].

Yeğinobalı, A. ve Dilek, F. T. placed concrete samples in 10% sodium sulfate and 8.4% magnesium sulfate solutions in their research. The best resistance was against sodium sulfate and it was observed at 16% silica fume addition. On the other hand, silica fume addition adversely affected the resistance against magnesium sulfate [6].

Mehta, P.K. has investigated the resistance of concretes having low water/cement ratio without admixtures, with latex, and with 15%

silica fume by weight of cement against several types of acids. Silica fume concrete has shown better resistance against 1% hydrochloric, 5% acetic, and 1% sulphuric acid solutions than the other two types of concrete [5].

In the research of Carlsson, M., Hope, R., and Pederson, J.; 5% silica fume concrete samples that are prepared for the construction of concrete pipes are placed in 10% sodium sulfate solution for 92 weeks, and they have shown lesser weight reduction than the pure concrete [8].

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

In this study, the resistance of concretes with 10% silica fume by weight of cement and concretes without any admixtures are tested against ammonium sulfate. Strength, weight change and length change of concrete samples are tested. The results of the tests have been tested by one-variable F-test in the light of "Silica fume concrete has resistance against the effects of ammonium sulfate" hypothesis.

3. EXPERIMENTAL STUDY (DENEYSEL ÇALIŞMA)

3.1. Material (Malzeme)

Unit weight of the aggregates used in the experiments is 2.646 kg/m³ and 2.785 kg/m³ for fine and coarse aggregates, respectively. Water absorption ratio for fine aggregate is found to be 1% and for coarse aggregate 0.5%. Maximum grain size of the aggregates was 16 mm. Silica fume is obtained from Eti Electrometallurgy Co.Inc. Facilities. 90% SiO_2 is present in its compound. Its unit weight is 2.20 kg/l. Portland cement (PÇ42.5) is used in the mix proportion of concrete. And finally drinking water is used in the mix proportion.

3.2. Method (Yöntem)

Water-cement ratio is taken to be 0.53 [9]. Cement amount in the mixture is 350 kg/m³ and water amount in the mixture is 185 lt/m³.

Table 1. Mix proportion of concrete (1 m³)
(Tablo 1. Beton karışım oranları (1 m³))

Mixture components	Kg/m³
Water	185
Cement	350
Silica fume (%)	36
Coarse aggregate (4/16)	1319.75
Fine aggregate (0/4)	463.69

In Table 1, the components of 1 m³ concrete are given. Solution: 2% ammonium sulfate (20 mg/lt) (TSEN 3440 – very harmful). Ammonium sulfate: total nitrogen (N) 21%. Ammonium nitrogen (21%) is obtained from Çelikkayalar CO.Inc. 3 samples of each 10% silica fume concrete and pure concrete have been prepared according to the mix proportions given in Table 1. Samples are cured in water for 7 days, later samples are placed in 2% ammonium sulfate solution for 28 days. At the end of 28 days, samples are tested for their strength, length and weight changes.

4. FINDINGS (BULGULAR)

The strength of 10% silica fume concrete and concrete without pozzolanic admixtures is tested. The strength of silica fume concrete is observed to be 18.29% higher than the pure concrete. Silica fume concrete has shown 0.541% lesser weight change. However, there wasn't a considerable difference in the length changes.

4.1. Test Result After 7-Day Period (7 Günlük Test Sonuçları)

4.1.1. Strength Values (Dayanım Değerleri)

Strength values obtained at the end of seventh day are given in Table 2 for the silica fume concrete. As can be seen from Table 2, strength values are higher for the silica fume concrete samples. On the other hand, concrete samples without pozzolanic admixtures have shown reduction in strength as given in Table 3.

Table 2. Strength values for the 10% silica fume concrete samples
(Tablo 2. 10'luk silis dumanlı beton numuneler için dayanım değerleri)

Sample No	Sample age (day)	Strength (kN)
1	7	382.8
2	7	399.5
3	7	386.4
4	7	387.5
5	7	391.4
	Mean(kN)	389.52

Table 3. Strength values for the concrete samples without pozzolanic admixtures
(Tablo 3. Puzolansız beton numuneler için dayanım değerleri)

Sample No	Sample age day)	Strength (kN)
1	7	328.8
2	7	319.5
3	7	323.5
4	7	322.6
5	7	325.2
	Mean(kN)	323.93

4.1.2. Length Changes (Boy Değişimleri)

Both silica fume concrete samples and pure concrete samples have shown no length change after being placed in ammonium sulfate solution for a 7-day period. The length changes of the samples are given in Table 4 and 5.

Table 4. Length changes of 10% silica fume concrete samples
(Table 4. 10'luk silis dumanlı beton numuneler boy değişimleri)

Sample No	Sample age (day)	Dimensions (mm)	
		Initial	Final
1	7	150×150×150	150×150×150
2	7	150×150×150	150×150×150
3	7	150×150×150	150×150×150
4	7	150×150×150	150×150×150
5	7	150×150×150	150×150×150

Table 5. Length changes of concrete samples without pozzolanic admixtures
(Tablo 5. Puzolan katkısız beton numuneler boy değişimleri)

Sample No	Sample age (day)	Dimensions (mm)	
		Initial	Final
1	7	150×150×150	150×150×150
2	7	150×150×150	150×150×150
3	7	150×150×150	150×150×150
4	7	150×150×150	150×150×150
5	7	150×150×150	150×150×150

4.1.3. Weight Change (Ağırlık Değişimleri)

Both silica fume concrete and pure concrete samples that are placed in 2% ammonium sulfate solution for a 7-day period have shown a decrease in weight. These weight changes are given in Table 6 and Table 7.

Table 6. Weight changes of 10% silica fume concrete samples cured in 2% ammonium sulfate solution for 7-days
(Tablo 6. 2%'lik amonyum sülfat çözeltisi içinde 7 gün bekletilen 10%'luk silis dumanlı beton numunelerde ağırlık değişimi)

Sample No	Sample age (day)	Weight (gr)		
		Before curing in water	After curing in water	After curing in ammonium sulfate solution
1	7	7700	7720	7710
2	7	7850	7880	7840
3	7	7830	7840	7830
4	7	7820	7830	7825
5	7	7810	7830	7815
Mean		7802	7820	7804
Weight Change(%)		100%	0.230%	-0.204%

Table 7. Weight changes of concrete samples without pozzolanic admixtures cured in 2% ammonium sulfate solution
(Tablo 7. 2%'lik amonyum sülfat çözeltisi içinde 7 gün bekletilen puzolansız beton numunelerde ağırlık değişimi)

Sample No	Sample age (day)	Weight (gr)		
		Before curing in water	After curing in water	After curing in ammonium sulfate solution
1	7	7700	7720	7690
2	7	7500	7510	7500
3	7	7710	7730	7700
4	7	7730	7760	7745
5	7	7560	7580	7560
Mean		7640	7660	7639
Weight Change(%)		100%	0.261%	-0.274%

4.2. Test Results After 28-day Period (28 Günlük Test Sonuçları)

4.2.1. Strength values (Dayanım değerleri)

According to the strength values presented in Tables 8 and 9, it is easily seen that, strength of 10% silica fume concrete samples that are placed in 2% ammonium sulfate solution for 28 days is 18,29% bigger than strength of pure concrete samples. In Figure 1, 7-28 day strength of concrete samples is shown.

Table 8. 28-day strength of 10% silica fume concrete samples
(Tablo 8. 10%'luk silis dumanlı beton numunelerde 28-günlük dayanım)

Sample No	Sample age (day)	Strength (kN)
1	28	456.4
2	28	463.9
3	28	447.0
4	28	455.3
5	28	465.5
	Mean	457.62

Table 9. 28-day strength of pure concrete samples
(Table 9. Puzolansız numunelerde 28-günlük dayanım)

Sample No	Sample age (day)	Strength (kN)
1	28	380.0
2	28	385.4
3	28	403.2
4	28	380.2
5	28	385.4
	Mean	386.84

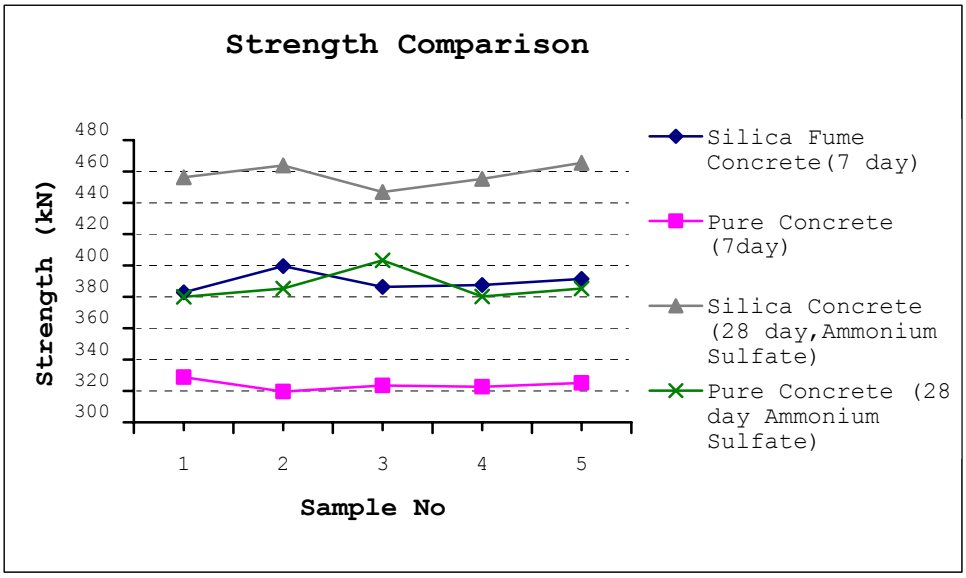

Figure 1. Comparison of 7-28 day strength of silica fume and pure concrete samples
(Şekil 1. 7-28 gün silis dumanlı ve silis dumansız beton numunelerinin basınç dayanımları)

4.2.2. Length Changes at the End of 28 Days (28 Gün Sonunda Boy Değişimleri)

No change is observed in the dimensions of silica fume and pure concrete samples that are cured in 2% ammonium sulfate solution for 28 days. The test results are shown in Table 10 and Table 11 for silica fume concrete samples and pure concrete samples, respectively.

Table 10. Length change of 10% silica fume concrete samples
(Table 10. 10%'luk silis dumanlı beton numunelerde boy değişimi)

Sample No	Sample age (day)	Dimensions (mm)	
		Initial	Final
1	28	150×150×150	150×150×150
2	28	150×150×150	150×150×150
3	28	150×150×150	150×150×150
4	28	150×150×150	150×150×150
5	28	150×150×150	150×150×150

Table 11. Length changes of pure concrete samples
(Tablo 11. Puzolansız numunelerde boy değişimi)

Sample No	Sample age (day)	Dimensions (mm)	
		Initial	Final
1	28	150×150×150	150×150×150
2	28	150×150×150	150×150×150
3	28	150×150×150	150×150×150
4	28	150×150×150	150×150×150
5	28	150×150×150	150×150×150

4.2.3. Weight changes at the End of 28-Days (28 Gün Sonunda Ağırlık Değişimleri)

The weight changes of concrete samples are presented in Table 12 and Table 13. Silica fume concrete samples have shown 0.541% lesser weight change. In Figure 2, 7-28 day weight changes of concrete samples is shown.

Table 12. Weight change of 10% silica fume concrete samples cured in 2% ammonium sulfate solution for 28 days
(Tablo 12. 2%'lik amonyum sülfat çözeltisi içinde 28 gün bekletilen 10%'luk silis dumanlı beton numunelerde ağırlık değişimi)

Sample No	Sample age (day)	Weight (gr)		
		Before curing in water	After curing in water	After curing in ammonium sulfate solution
1	28	7900	7920	7890
2	28	7950	7960	7930
3	28	7850	7850	7840
4	28	7920	7925	7910
5	28	7850	7865	7845
Mean		7894	7904	7883
Weight Change(%)		100%	0.126%	-0.265%

Table 13. Weight change of pure concrete samples cured in 2% ammonium sulfate solution for 28 days
(Tablo 13. %2'lik amonyum sülfat çözeltisi içinde 28 gün bekletilen pozolansız beton numunelerde ağırlık değişimi)

Sample No	Sample age (day)	Weight (gr)		
		Before curing in water	After curing in water	After curing in ammonium sulfate solution
1	28	7200	7220	7150
2	28	7500	7510	7470
3	28	7690	7730	7670
4	28	7300	7330	7250
5	28	7400	7425	7375
Mean		7418	7443	7383
Weight Change (%)		100%	0.337%	-0.806%

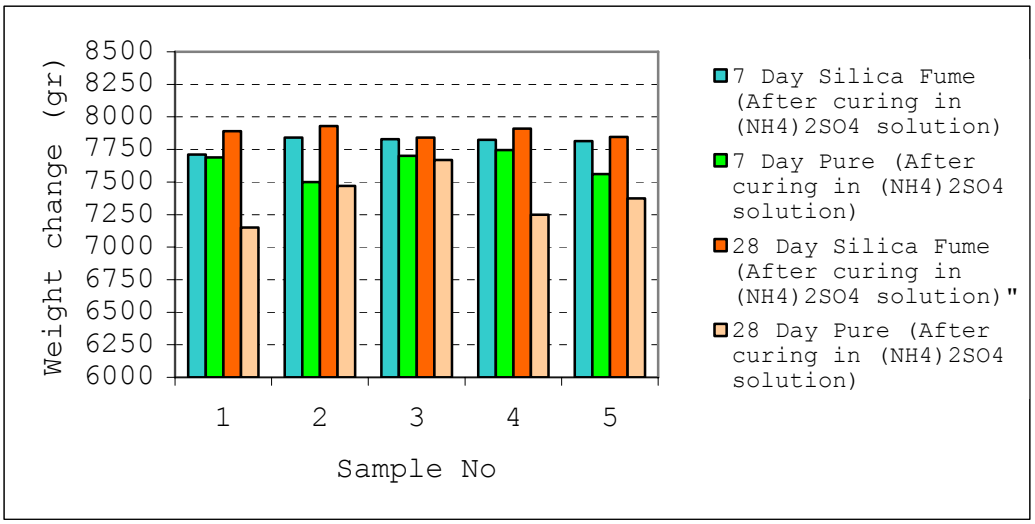

Figure 2. 7-28 day Weight change of silica fume and pure concrete samples
(Şekil 2. 7-28 gün silis dumanlı ve silis dumansız beton numunelerinin ağırlık değişimleri)

5. CONCLUSION AND RECOMMENDATIONS (SONUÇ VE ÖNERİLER)

Silica fume concrete samples with 10% silica fume by weight of cement and with dimensions 150x150x150 mm have shown 18.29% better compressive strength values than the concrete samples without any pozzolanic admixtures. No length change is observed in the samples. Silica fume concrete samples have shown greater weight change.

It has been determined that silica fume additive are more strength and more durability than the corrosion effect of ammonium sulfate. It is clearly seen that the increase performance in concrete samples on Figure 1 and Figure 2.

According to the variance analysis results performed on the test data, silica fume concrete has better resistance against ammonium sulfate.

As a result, in the construction of concrete pipes and foundations those are under the effect of ammonium sulfate, addition of silica fume to the cement paste when producing concrete is an effective way. Especially in the farmlands, since the effect of ammonium sulfate is high, silica fume concrete production is extremely important.

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