THE EXPERIMENTAL STUDY ABOUT THE USAGE OF SILICA FUME IN MORTAR PLASTER PRODUCTION

M.Haluk CELIK*, Aykut DEGIRMENCI*

Özet- Bu çalışmada, silis dumanının sıva harcıyla olan ilişkisi araştırılmıştır. Bu amaçla silis dumanı, %0, %5, %10 ve %15 oranlarında çimentonun ağırlıkça yerine kullanılmıştır. Silis dumanının sıva harcındaki; kıvam, boşluklu birim hacim kütlesi, eğilme dayanımı, basınç dayanımı, alt tabakaya yapışma dayanımı ve su emme özellikleri üzerine olan etkisi deneysel olarak incelenmiştir.

Deney sonuçlarında; kıvam, taze harcın boşluklu birim hacim kütlesi ve su emme değerleri silis dumanı oranı arttıkça azalmış ve eğilme, basınç ve yapışma dayanımında artış gözlenmiştir.

Anahtar Kelimeler: Sıva, silis dumanı, kıvam, harç, puzolan, basınç dayanımı, eğilme dayanımı, yapışma dayanımı, su emme.

Abstract- In this study; the relation between silica fume and mortar plaster was investigated. For that reason; silica fume was replaced with 0%, 5%, 10%, 15% of cement weight. The effect of silica fume on consistency, unit volume mass, bending strength, compressive strength, water absorbtion and adhesive strength of mortar plaster were investigated by experimental methods.

In the experiment results; it was seen that consistency, unit volume mass and water absorbtion values of fresh concrete have decreased by increasing silica fume ratio and also it could be seen that; as the silica fume ratio have been increased, bending, compressive and adhesive strength have increased.

Keywords: Pozzolan, silica fume, consistency, mortar plaster, compressive strength, adhesive strength, bending strength, water absorbtion.

I. INTRODUCTION

The plastering work is done for sealing of wall surfaces in the construction, to have a good outface and inner appearance, to protect the building from external effects and to isolating against the sound, heat and moisture.[1]

Silica fume is apozzolanic substance that is obtained as a by-product during the production of silisium and ferrosilisium alloys in 200 ˚C heated electric arc oven.

The first studies about the usage of silica fume, which is obtained as an industrial waste during the production of silisium metal or ferrosilisium alloys, was started in Norway in 1950 in order to provide environmental protection.[2]

Nowadays, silica fume is used as a bonding material in concrete or mortar production by mixing at a ratio of weight percentage of portland cement instead of some amount of cement or it is mixed with cement in the beginning and used as an admixture in the production of cement.

In Turkey silica fume is obtained in Etibank Elektrometalurji A.Corp. establishment in Antalya.The annual amount of production from ferrosilisium and silicoferrochrome chimney dusts varies between 1000-2000 tons. The silica fume obtained from establishment is used as an admixture in the cement and concrete and is used especially in several investigations that have been made in the universities since the end of 1980.[2]

The aim of this study is to consider the evaluation of industrial wastes and to research the effect of silica fume, which is an industrial waste, on mortar plaster. For that reason, silica fume was used by substituting with 0%, 5%, 10% and 15% of cement by weight. The determination of physical and mechanical characteristics of mortar was aimed.

* Gazi University, Faculty of Technical Education, Dept. of Construction, Ankara - TURKEY

II. LITERATURE REVIEW

Kılınçkale has investigated the pozzolanic activity and caracteristics of artificial pozzolans like high oven slag, flying ash, silica fume, rice shell in his study.The silica fume is substituted 20% of cement weight in portland cement and pozzolanic mortar is obtained.The bending and compressive strength of the mortar are determined in 7th and 28th day after production. As a result it is determined that whole poizzolans have pozzolanic activity.Also it is determined that the silica fume and rice shell ash have the most pozzolanic activity in those pozzolans.[3]

Çark and Sümer produced concretes by substituting silica fume with cement weight at a ratio of 0%, 5%, 10%.They cured those produced concretes at a temperature of 5˚C, 22˚C, 39˚C, 52˚C. At the end of 28 days the compressive strengths were measured. In the end of experiment it was seen that the usage of silica fume as an admixture in concrete at defined amounts have increased the compressive strength of the concrete at a very big ratio. Also it was determined that, to increase the curing temperature until a limited value had positive effect on concrete strength.[4]

Ekinci and Yeğinobalı have measured the weights of cubic concrete specimens having 100×100×100 mm dimensions, that were prepared with substititing ferrosilisium and silico ferrochrome chimney dusts with 0%, 10%, 15%, 20%, 25%, 30% of cement weight, before and after the experiment, and also they measured their electoronic puls passing velocity and determined the compressive strength.in the results it was seen that the addition of silica fume in the concrete has positive effect on striking strength of concrete. However, when the ratio of addition was more than 20%, the positive effect have decreased a little which was different from static load strength.[5]

In their studies, Aköz, Yüzer and Koral, has heated the normal mortar and the mortar that were prepared with 10% addition of silica fume until 100, 200, 300, 600, 900, 1200 ˚C to see the effect of high temperature on mortar's physical and mechanical characteristics. In the results of experiment it was determined that high temperature has similar effects on physical characteristics of both normal mortar and the mortar including silica fume. However, it was seen that at the temperatures higher than 600 ˚C; the mortar including silica fume had bigger loss in durability than normal mortar. Also they determined that colling in water has more negative effect than cooling with air, at every temperature.[6]

Ekinci has indicated that silica fume affected the consistency in a bad way and when it was added at a high ratio, more water will be needed therefore; to obey the standard requirements the usage of super liquefier would be necessary and the usage of SL would increase the costs.[7]
The transportation of silica fume is a problem since it is a very light substance. The usage of this material can be suitable by mixing it with water and it can be transported as a mixture and can also be used by compress ad air.[8]

III.MATERIAL AND METHOD

III.1. Material

The mixture of mortar plaster consists of $1m^3$ sand, 250 kg cement, 0.1 m^3 lime and 0.2 m^3 water. In the mixture; PC 42.5 cement, slaked lime and network water had been used. The silica fume that was used as an additive in the mixture had been obtained from Etibank Elektrometalurji A.Ş establishment in Antalya. In the mixture silica fume is used by substituting with 0%, 5%, 10% and 15% of cement weight. In the experiments every specimens were poured into molds three at a time and the results were investigated.The sieve analysis of the sand used in mixture is shown in Table 1.

Table-1: Sieve Analysis [EN 1015-1]

Diameter of sieve (mm)	Mass Retained (gr)	Retained (%)	Cumulative Retained (%)	Passing (%)
2,0	0	0	0	100
1,0	1498	29,96	29,96	70,04
0,5	446	8,92	38,88	61,12
0,25	2598	51,96	90,84	9,16
Pan	458	9,16	100	-

III.2. Method

III.2.1. Preperation of experiment samples

The mortar, with which the dry mixture elements will be mixed before the usage of water, was prepared according to EN 1015-2 requirements.

In the determination of consistency of fresh mortar plaster experiment, the conic cut molds were used, the dimensions of molds were; 60mm ± 5mm in height, 100mm ± 0.5mm in inner base diameter and 70mm ± 0.5mm in upper surface diameter. The thickness of mold wall was 2.0 mm.

In determination of bending and compressive strength experiment, the molds having 40×40×160 mm dimensions were used.Each specimen were poured into molds three times and firstly the bending strength experiment has been done. After bending strength experiment had been done compressive strength experiment was done.

In sticking strength experiment, concrete rectangular panels having minimu 550×150mm dimensions and minimum tickness of 50 mm were used. The fresh mortar plaster have been treated to concrete panel in 10 mm ± 1mm thickness and epoxy was given.

III.2.2. Determination of consistency of fresh mortar plaster

According to EN 1015-3 requirements; by the help of molds the fresh mortar plaster was placed on the spreading table which mets requirements, then the spresding table was lifted up and set free, the spreading value of fresh mortar plaster was measured by measuring the diameter of mortar plaster which was spred.

III.2.3. Determination of unit volume mass

According to EN 1015-6 requirements; the fresh mortar plaster has been placed on a measurement container, which has a definite volume, by using defined methods or by compressing it and the unit volume mass is found by dividing the mass of fresh mortar plaster to the volume that was occupied.

III.2.4. Determination of bending strength of hardened mortar plaster

According to EN 1015-11 requirements; the bending strength of mortar plaster has been determined by increasing the load which was applied on the prismatic hardened mortar plaster specimens, which were prepared by pouring into molds, until they yield from three points.

III.2.5. Determination of compressive strength of fresh mortar plaster

According to EN 1015-11 requirements; the compressive strength of mortar plaster has been determined by using the two prismatic particles that were obtained from bending strength test.Although it was needed for determining bending strength, for determining compressive strength, the particles that were obtained from any process that had not damaged the particles, had been used.

III.2.6. Determination of adhesive strength of hardened mortar plaster and bonding mortar plaster to lower layer

According to EN 1015-12 requirements; the adhesive strength is defined as the pulling stretch that occurs by applying direct loads on the surface of mortar plaster and bonding mortar that has been applied to lower layer.The pulling load has been applied to experimental area on the concrete surface by sticking pulling headed plaq.

III.2.7. Determination of water absorbtion values

The absorbtion characteristics of material is determined by following method; The material is weighed in dry state,W_1, it is kept in water 24 or 48 hours till its weight stays constant.It is taken from water and its surface is dried and weighed again, W_2, The water absorbtion as weight percentage is found by using the following equation.

$$Sa = [(W_2-W_1)/W_1]*100\%$$

IV. FINDINGS AND EVALUATION

The results of experiment in the given method, the tables are given in illustrated figures and the reliability is investigated by using variance method.

IV.1. Determination of consistency of fresh mortar plaster

As mentioned in part III.2.2; the consistency experiment results of mortar plaster are given in table 2 and figure 1.

Table-2: Consistency Experiment Results

Experiment No	Pure Sample (0%) (mm)	5% SF Added Sample (mm)	10% SF Added Sample (mm)	15% SF Added Sample (mm)
1	135	128	124	120
2	138	130	122	118
3	136	129	123	116

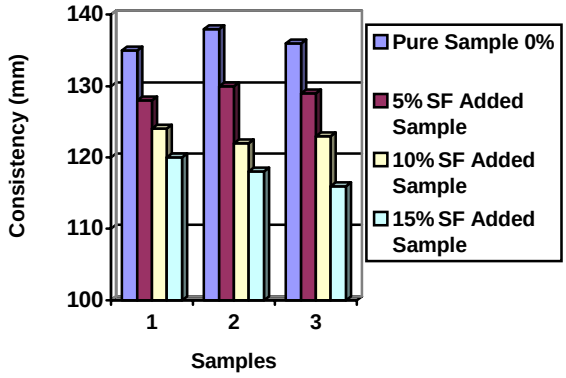

Figure-1: Consistency Experiment Distribution Graph

IV.2. Unit volume mass of fresh mortar plaster that have voids

As mentioned in part III.2.3; According to the results of consistency experiment the unit volume mass values are given in table 3 and figure 2.

Table-3. Unit volume mass of fresh mortar plaster that have voids

Experiment No	Pure Sample (0%) (kg/m^3)	5% SF Added Sample (kg/m^3)	10%SF Added Sample (kg/m^3)	15%SF Added Sample (kg/m^3)
1	312	295	286	277
2	318	300	282	272
3	314	298	284	268

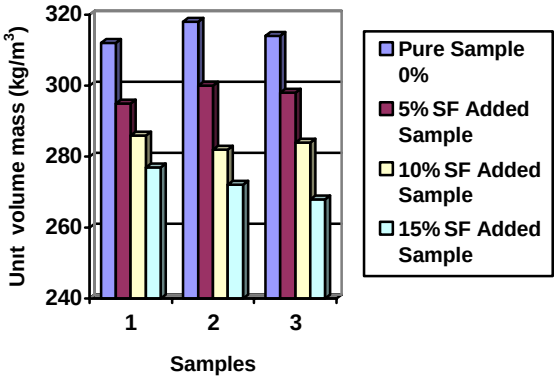

Figure-2: The distribution graph of voided unit volume of fresh mortar plaster

IV.3. Determination of bending strength of hardened mortar plaster

As mentioned in part III.2.4.7 days bending strength results of mortar plaster are given in table 4 and figure 3.

Table-4: 7 Days Bending Strength Results

Experiment No	Pure Sample (0%) (N/mm^2)	5 % SFAdded Sample (N/mm^2)	10% SF Added Sample (N/mm^2)	15% SF Added Sample (N/mm^2)
1	1,43	1,617	1,688	1,935
2	1,477	1,617	1,781	2,016
3	1,523	1,594	1,641	1,837

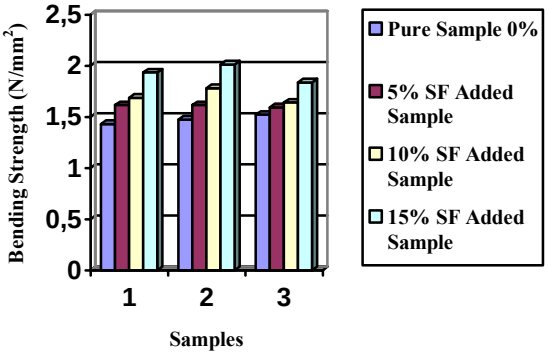

Figure 3: 7 Days Bending Strength Distribution Graph

* 28 days bending strength results are given in table 5 and figure 4.

Table-5: 28 Days Bending Strength Results

Experiment No	Pure Sample (0%) (N/mm^2)	5 % SFAdded Sample (N/mm^2)	10 %SF Added Sample (N/mm^2)	15 %SF Added Sample (N/mm^2)
1	3,456	3,465	3,54	3,605
2	3,452	3,455	3,506	3,584
3	3,395	3,483	3,562	3,584

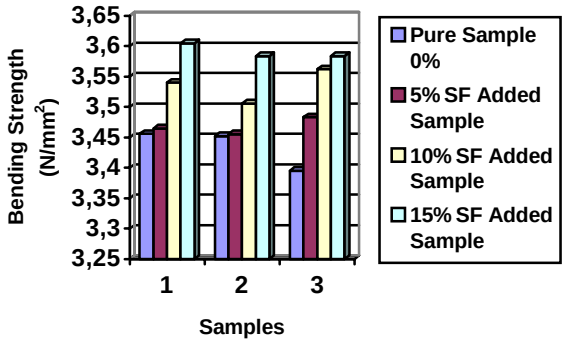

Figure 4 : 28 Days Bending Strength Distribution Graph

VI.4. Determination of compressive strength of fresh mortar plaster

As mentioned in part III.2.5; 7 days compressive strength results are given table 6 and figure 5.

Table-6: 7 Days Compressive Strength Results

Experiment No	Pure Sample (0%) (N/mm^2)	5% SFAdded Sample (N/mm^2)	10% SF Added Sample (N/mm^2)	15% SF Added Sample (N/mm^2)
1	4,497	4,598	4,603	4,754
2	4,565	4,567	4,624	4,685
3	4,583	4,602	4,621	4,702

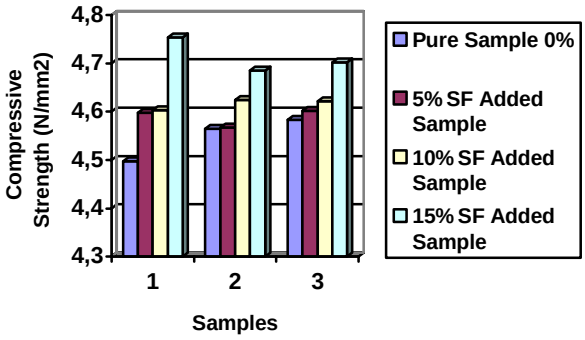

Figure -5: 7 Days Compressive Strength Distribution Graph

* 28 days compressive strength results are given in table 7 and figure 6.

Table-7: 28 Days compressive strength results

Experiment No	Pure Sample (0%) (N/mm^2)	5% SFAdded Sample (N/mm^2)	10% SF Added Sample (N/mm^2)	15% SF Added Sample (N/mm^2)
1	16,997	17,489	18,188	18,464
2	17,030	17,158	18,242	18,155
3	16,443	17,352	18,059	18,383

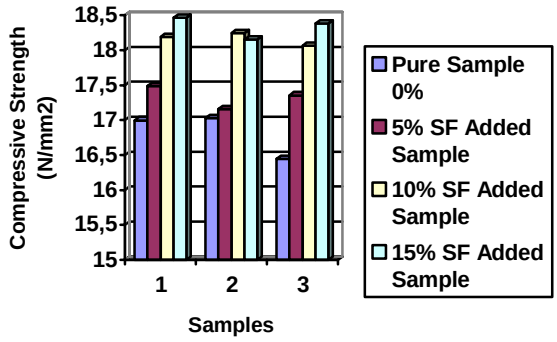

Figure -6 : 28 Days Compressive Strength Distribution Graph

VI.5. Determination of adhesive strength of hardened mortar plaster and bonding mortar to lower layer

As mentioned in part III.2.6; adhesive strength experiment results are given in table 8 and figure 7.

Table-8 : Adhesive Strength Experiment Results

Experiment No	Pure Sample (0%) (N/mm^2)	5% SFAdded Sample (N/mm^2)	10% SF Added Sample (N/mm^2)	15% SF Added Sample (N/mm^2)
1	0,62	0,61	0,612	0,625
2	0,604	0,602	0,613	0,63
3	0,614	0,598	0,613	0,633

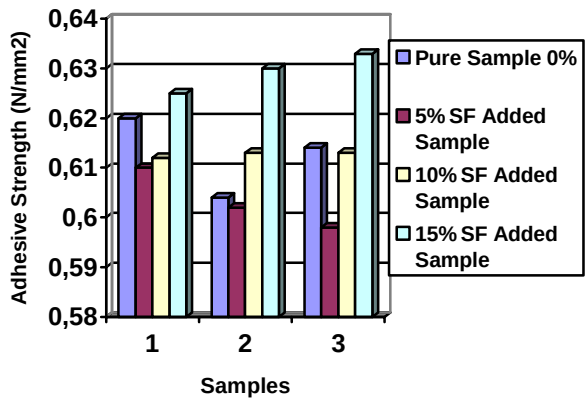

Figure-7: Adhesive Strength Distribution Graph

VI.6. Determination of water absorbtion values

As mentioned in part III.2.7; water absorbtion values are given in table 9 and figure 8.

Table-9 : Water Absorbtion Values

Experiment No	Pure Sample (0%) (%)	5% SFAdded Sample (%)	10% SF Added Sample (%)	15% SF Added Sample (%)
1	9,39	6,59	6,88	7,13
2	9,52	6,28	5,05	5,63
3	9,56	6,45	5,52	6,95

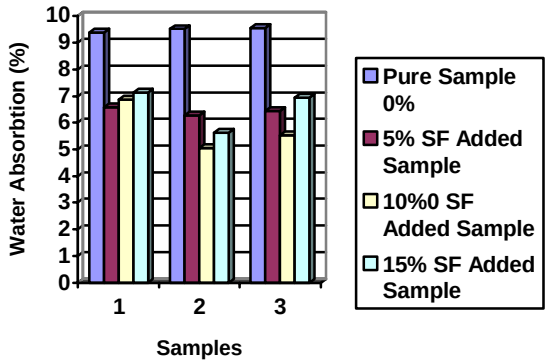

Figure-8 : Water Absorbtion Distribution

VI.7. One-way variance analysis of experiments

To investigate the reliability of the results of consistency, unit volume mass, bending strength, compressive strength, adhesive strength and water absorbtion experiments, the mathematical equation is assembled as $Y_{ij}=\mu+T_j+E_{ij}$ and the following results are obtained.

The result of consistency experiment are found as the following: The sum of general squares, SSg = 578.917, the sum of squares in trial period; SStr = 562.250, the sum of squares of errors; SSe = 16.667, the average of general squares MSSg = 187.417, the average of squares of ; MSSe = 5.556. According to these data, $F_{calculation}$ = 33.735>F_{table}= $_{95}F_{3.8}$ = 4.07 equation was found and it can be said that the addition of silica fume decreases the consistency of mortar plaster.

The results of 7 days bending strength were calculated as; SSg = 0.358, SStr = 0.327, SSe = 0.031, MSSg = 0.109, MSSe = 0.010. According to obtained data $F_{calculation}$ = 10.588 was found. $F_{calculation}$ = 10.588 > F_{table} = $_{95}F_{3.8}$ = 4.07.

The result of 28 days bending strength are calculated as; SSg = 0.049, SStr = 0.327, SSe = 0.005, MSSg = 0.015, MSSe= 0.002.According to obtained data $F_{calculation}$ = 9.567 was found. Since $F_{calculation}$ = 9.567 >

$F_{table} = {}_{95}F_{3.8} = 4.07$,it was seen that the addition of silica fume increased the bending strength of mortar plaster.

The results of 7 days compressive strength was calculated as; SSg = 0.052, SStr = 0.045 SSe = 0.008, MSSg = 0.015, MSSe = 0.003.According to obtained data $F_{calculation} = 5.790$ was found. $F_{calculation} = 5.790 > F_{table} = {}_{95}F_{3.8} = 4.07$.Then results of 28 days compressive strength were calculated as: SSg= 4.884, SStr =4.542, SSe = 0.342, MSSg = 1.514, MSSe = 0.114. According to obtained data $F_{calculation} = 13.283$ was found. Since $F_{calculation} = 13.283 > F_{table} = {}_{95}F_{3.8} = 4.07$ it was seen that the addition of silica fume increased the compressive strength of mortar plaster.

The results of adhesive strength were calculated as SSg = 0.001, SStr = 0.001, SSe = 0.0002, MSSg = 0.0004, MSSe=0.0001. According to obtained data $F_{calculation} = 4.418$ was found. Since $F_{calculation} = 4.418 > F_{table} = {}_{95}F_{3.8} = 4.07$ it was seen that the addition of silica fume increased the adhesive strength of mortar plaster.

The results of water absorbtion were calculated as; SSg = 27.381, SStr = 24.173, SSe = 3.208, MSSg = 8.058, MSSe = 1.069. According to obtained data $F_{calculation} = 7.536$ was found.$F_{calculation} = 7.536 > F_{table} = {}_{95}F_{3.8} = 4.07$ it was seen that the addition of silica fume is generally decreased water absorption value of mortar plaster

V. CONCLUSIONS

In the consistency experiment's results, the consistency values of the prepared specimens were found as 136,33, 129, 123, 118 respectively. As the ratio of silica fume increased, the spreading value have decreased. Since it has very tiny particles in its formation, the specific surface of silica fume is greater than the cement.The specific surface is 13000 - 20000 kg/m^2.Because of that reason more water was needed and consistency values have decreased.

In the results of experiment of determination of unit mass volume of fresh mortar plaster; the density volumes are determined as 314.667 kg/m^3 , 297.667 kg/m^3, 284.00 kg/m^3, 272.333 kg/m^3 respectively. In this situation, it can be said that, as the silica fume ratio increased the unit volume mass decreased.

In the results of bending strength determination experiment, the 7 days results were found as 1.477 N/mm^2, 1.609 N/mm^2, 1.703 N/mm^2, 1.929 N/mm^2 respectively.The sample that has 15% additive has showed 30% greater strength then the pure sample. 28 days strength were found as 3.434, 3.536, 3.536, 3.591 N/mm^2 respectively.
In the results of compressive strength experiment; the 7 days values are found as 4.548, 4.589, 4.616, 4.714 N/mm^2 respectively. The 28 days results were found as 12.823, 17.333, 18.163, 18.334 N/mm^2 respectively.It was seen that as the additive ratio increases the compressive strength increases.The increase in 28 days values are greater than the 7 days values.

In the results of adhesive strength experiment; the obtained results are 0.613, 0.603, 0.613, 0.629 N/mm^2 respectively. When the silica fume ratio increases, the adhesive strength increases. Since the silica fume has very tiny particles it can easily hold on the surface and increses the adhesive strength.

In the results of water absorbtion experiment; the values are found as 9.49% 6.44%, 5.817%, 6.57% respectively. As the silica fume ratio increases water absorbtion values decreases.

Since the silica fume is an industrial waste, its usage in mortar plaster production will protect environment againist silica fume and its usage will also provide benefit for economy. Also the limited natural sources will be used less.

REFERENCES

[1] Güner, M.S., Yüksel, A., Structural Knowledge, P.327-329, Aktif Press, Erzurum, 2001 (In Turkish).
[2] Yeginobali, A., Silica Fume And Its Usage In Concrete Within Cement, Tcmb/Ar-Ge/ Ankara, 2001 (In Turkish).
[3] Kilinckale, F. M., The Pozzolanic Activity Of Several Pozzolans And The Strength Of Concretes Produced With These Pozzolans
[4] Cark, A.I., Sumer, M., The Strength Analysis Of Concrete Including Sf Under Differrent Cure Conditions, 4th International Concrete Congress, 30-31 Of October-1 Of November, Istanbul, 1996.
[5] Ekinci, C.E., Yeginobali, M.A., The Striking Strength Of Silica Fume Added Concretes, 4th International Concrete Congress, 30-31 Of October-1 Of November, Istanbul, 1996.
[6] Aköz, F., Yüzer, N., Koral,S., The Effect Of High Temperature On Concretes That Have Sf And Portland Cement , Technical Magazine, Cilt:6 Number:2 , January, 1995
[7] Ekinci, C.E., Antalya Etibank Elektrometalurji Işletmesi Silis Dumanlarinin Çimento Ve Betonda Katki Maddesi Olarak Değerlendirilmesi, Doktora Tezi, Firat University, 1995 (In Turkish).
[8] Temiz, H., Properties Of Mortar Added Fly Ash And Silica, Phd. Thesis, Firat University, 1997 (In Turkish).
[9] EN 1015-1:1998 EQV, Methods of test for mortar for masonry - Part 1: Determination of particle size distribution (by sieve analysis), 1998.
[10] EN 1015-2:1998 EQV, Methods of test for mortar for masonry - Part 2: Bulk sampling of mortars and

preparation of test mortars, 1998.
[11] EN 1015-3:1999 EQV, Methods of test for mortar for masonry- Part 3: Determination of consistence of fresh mortar (by flow table), 1998.
[12] EN 1015-6:1998 EQV, Methods of test for mortar for masonry - Part 6: Determination of air content of fresh mortar, 1998.
[13] EN 1015-9:1999 EQV, Methods of test for mortar for masonry- Part 9: Determination of workable life and correction time of fresh mortar, 1999.
[14]EN 1015-11:1999 EQV, Methods of test for mortar for masonry- Part 11: Determination of flexural and compressive strength of hardened mortar, 1999.
[15] EN 1015-12:2000 EQV, Methods of test of mortar for masory- Part 12: Determination of adhesive strength of hardened rendering and plastering mortars on substrates, 2000.
[16] Çelik, M. H., Experimental Design and Analyses Method, Lecturer Notes, Gazi University, Institute Science and Technology, Dept. of Construction Education, Ankara, Turkey, 2003 .