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Full Length Research Paper

Effect of mineral admixtures on properties of lightweight pumice concrete

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In this study 25 different types of concrete have been produced. Pumice used as an aggregate and 0, 5, 10, 15 and 20% fly ash and each fly ash ratio has 0, 5, 10, 15 and 20% silica fume was added to replace cement. The physical and mechanical properties of concrete have been investigated. This study shows that, according to the rates of substitution compressive strength has very different characteristics. In terms of workability of concrete, an increase in the amount of silica fume substitution affects fresh concrete workability in a negative manner whereas an increase in the amount of fly ash substitution increases fresh concrete workability. No meaningful relationship is observed in concrete series in terms of surface hardness and ultrasonic transmission rate.

Key words: Lightweight concrete, pumice, silica fume, fly ash.

INTRODUCTION

In concrete construction, the concrete represents a very large proportion of the total load on the structure, and there are clearly considerable advantages in reducing its density. One of the ways to reduce the weight of a structure is the use of lightweight aggregate concrete (Mouli and Khelafi, 2008).

Lightweight aggregate concrete (LWAC) allows designer to create some solutions more flexibly and induce the economies. Indeed, the reduction of structural dead load makes it possible to use longer spans or decrease the section of structural elements, and reduce the amount of the required steel and even the foundation dimensions. In prefabrication, LWAC also makes it possible to reduce the placement and transportation costs. Beside its technical and economic interests, LWAC can be integrated into the demarche of sustainable development by using in particular artificial aggregates which are lighter than natural aggregates. Their uses preserve natural resources. Moreover, these concretes contribute to decrease demolished waste volume when they do not work, thanks to the optimization of the structures by providing less dead load. Thus, these new concretes fulfill the current requirements of waste minimization perfectly. Because of their greater porosity, lightweight aggregates (LWA) have less strength and are more deformable than normal-weight aggregates (Ke et al., 2009).

LWAC is manufactured by using different kinds of lightweight aggregates, available in nature or artificially produced, so that the properties of LWAC depend on the properties of the particular lightweight aggregate being used. Natural lightweight aggregate sources can be found in regions characterized by volcanic activity, where

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Table 1. Chemical properties of the cement.

Loss on ignition (%)	Cl- (%)	SO3 (%)
3.89	0.002	2.68

Table 2. Mechanical and physical properties of the cement.

Compressive strength 2 days (N/mm^2)	Compressive strength 28 days (N/mm^2)	Initial set (min)	Volume stability (mm)
24.8	50.1	186	1

Table 3. Chemical composition of fly ash.

SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	SO_3 (%)	Na_2O (%)	K_2O (%)
50.77	21.13	6.17	12.44	4.53	1.33	0.24	2.54

porous rocks (known as pumices) are available. Artificial lightweight aggregates (like the expanded clay obtained by thermal treatment of argillaceous materials) are produced in many countries, the raw materials being very common (Subaşi, 2009). Nowadays, there has been development in the industrial fields. Thus with development, industrial waste management policy such as recycle of wastes, using waste as new raw materials etc. becomes very important. In the civil engineering field, the use of waste materials partially or totally, instead of conventional materials has increased due to the economical and environmental reason (Beycioğlu, 2008).

In view of the global sustainable development, it is imperative that supplementary cementing materials be used to replace cement in the concrete industry. The most worldwide available supplementary cementing materials are silica fume (SF), a by-product of silicon metal and fly ash (FA), a by-product of thermal power stations, and blast-furnace slag (BS), a byproduct of steel mill. Supplementary cementing materials such as fly ash, ground granulated blast furnace slag (GGBS) and silica fume (SF) are widely used in concrete to improve the workability and strength or to reduce the costs (Malhotra and Mehta, 2002; Shui et al., 2010). The use of additional cementitious materials due to economic, technical and environmental considerations has become very common in modern concrete construction (Koçak, 2010).

In this study 25 different types of concrete have been produced. Pumice used as an aggregate and 0, 5, 10, 15 and 20% fly ash and each fly ash ratio has 0, 5, 10, 15 and 20% silica fume was added to replace cement . The physical and mechanical properties of concrete have been investigated.

MATERIALS AND METHODS

The lightweight aggregate used in the study is pumice aggregate obtained from Isparta-Gölcük region. Pumice aggregate is washed, sifted and used being classified as 0-4, 4-8, 8-16 mm. Portland cement (EN 197-1 CEM I 42.5 R) produced by the cement factory of Göltaş Göller Region is used as the binder. Some chemical, physical and mechanical properties of CEM I 42.5 R cement are given in Tables 1 and 2.

In the study, mains water of Süleyman Demirel University Western Campus is used as the mixing water. Fly ash (FA) and silica fume (SF) used in the study are provided from Muğla Yatağan fossil fuel plant and Antalya Eti Elektro Metalurji Inc., respectively. Chemical compositions of fly ash and silica fume are given in Tables 3 and 4, respectively. Sikament NP super plasticizer concrete admixture is used in the study. The selected super plasticizer is an appropriate concrete admixture for ASTM C 494 (2002) Type F with increasing early and final strength by decreasing mixing water to a great extent or increasing liquidity of concrete with the same amount of water. In order to determine the workability of fresh concrete, slump cone method based consistency test is performed in accordance with TS EN 12350-2. In addition, Fresh Concrete Unit Weight experiment -in accordance with TS 2941 (1991) is conducted on concrete samples freshly poured into moulds in order to determine the unit weight of fresh concrete samples in each series.

The following hardened concrete experiments are conducted: Compressive strength (TS EN 12390-3; 2001), approximate compressive strength by concrete surface hardness method,

Table 4. Chemical composition of silica fume.

SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	SO_3 (%)
91	0.58	0.24	0.71	0.33	1.06

Table 5. The amounts of material in 1 m^3 concrete composition.

Sample code	Cement (kg)	Aggregate (mm)			SP (kg)	FA (kg)	SF (kg)
		0-4	4-8	8-16			
FA0SF0	350.00	434	359	442	3.5	0	0
FA0SF5	332.5	432	358	440	3.5	0	17.5
FA0SF10	315	431	357	439	3.5	0	35
FA0SF15	297.5	429	355	437	3.5	0	52.5
FA0SF20	280	428	354	436	3.5	0	70
FA5SF0	332.5	433	358	441	3.5	17.5	0
FA5SF5	315.00	432	357	440	3.5	17.5	17.5
FA5SF10	297.50	430	356	438	3.5	17.5	35
FA5SF15	280	429	355	437	3.5	17.5	52.5
FA5SF20	262.5	428	354	435	3.5	17.5	70
FA10SF0	315	433	358	440	3.5	35	0
FA10SF5	297.5	431	357	439	3.5	35	17.5
FA10SF10	280	430	356	438	3.5	35	35
FA10SF15	262.5	428	355	436	3.5	35	52.5
FA10SF20	245	427	353	435	3.5	35	70
FA15SF0	297.5	432	358	440	3.5	52.5	0
FA15SF5	280	431	356	439	3.5	52.5	17.5
FA15SF10	262.5	429	355	437	3.5	52.5	35
FA15SF15	245	428	354	436	3.5	52.5	52.5
FA15SF20	227.5	427	353	434	3.5	52.5	70
FA20SF0	280	432	357	439	3.5	70	0
FA20SF5	262.5	430	356	438	3.5	70	17.5
FA20SF10	245	429	355	437	3.5	70	35
FA20SF15	227.5	427	354	435	3.5	70	52.5
FA20SF20	210	426	353	434	3.5	70	70

unit weight and ultrasonic measurement on concrete (ASTM C 597). The amounts of material in 1 m^3 concrete determined with respect to TS 2511 are given in Table 5.

RESULTS AND DISCUSSION

Unit weight experiment is conducted on fresh concrete samples in accordance with TS 2941. The unit weights of each concrete series obtained from the experiment are given in Table 6. Slump test is performed on fresh concrete samples in accordance with TS EN 12350-2 (2009) in order to determine the workability of concrete series. The change in the amount of slump when FA is kept constant and SF is variable is seen in Figure 1, whereas the change in the amount of slump when SF is kept constant and FA is variable is seen in Figure 2. Unit weight experiment is conducted on hardened concrete samples. The unit weights of each concrete series obtained from the experiment are given in Table 7. Compressive strength experiments are performed on

Table 6. Unit weights of fresh concrete samples.

Concrete code	Average unit weight (gr/cm^3)	Concrete code	Average unit weight (gr/cm^3)	Concrete code	Average unit weight (gr/cm^3)	Concrete code	Average unit weight (gr/cm^3)	Concrete code	Average unit weight (gr/cm^3)
FA0SF0	1.77	FA5SF0	1.77	FA10SF0	1.78	FA15SF0	1.74	FA20SF0	1.75
FA0SF5	1.80	FA5SF5	1.80	FA10SF5	1.79	FA15SF5	1.78	FA20SF5	1.76
FA0SF10	1.78	FA5SF10	1.78	FA10SF10	1.77	FA15SF10	1.79	FA20SF10	1.75
FA0SF15	1.78	FA5SF15	1.78	FA10SF15	1.77	FA15SF15	1.80	FA20SF15	1.75
FA0SF20	1.77	FA5SF20	1.77	FA10SF20	1.76	FA15SF20	1.78	FA20SF20	1.75

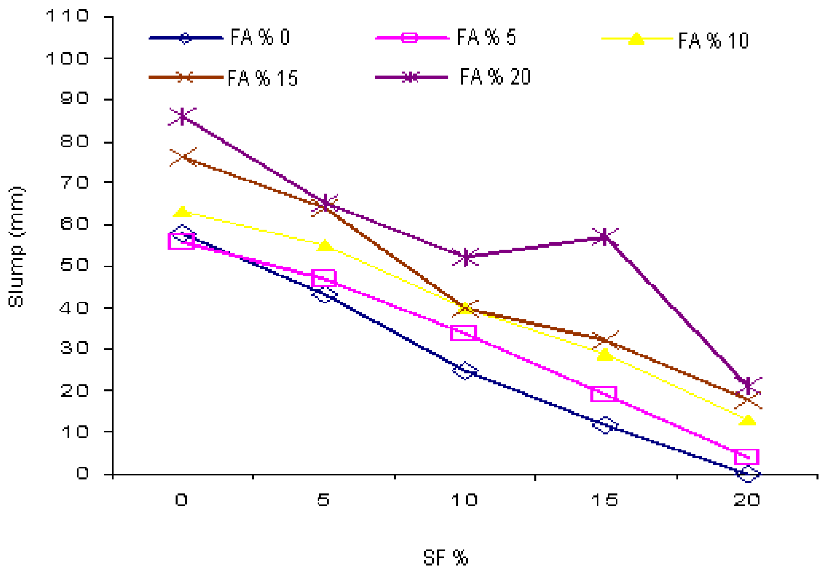

Figure 1. Change in the amount of slump with respect to SF ratio (FA constant).

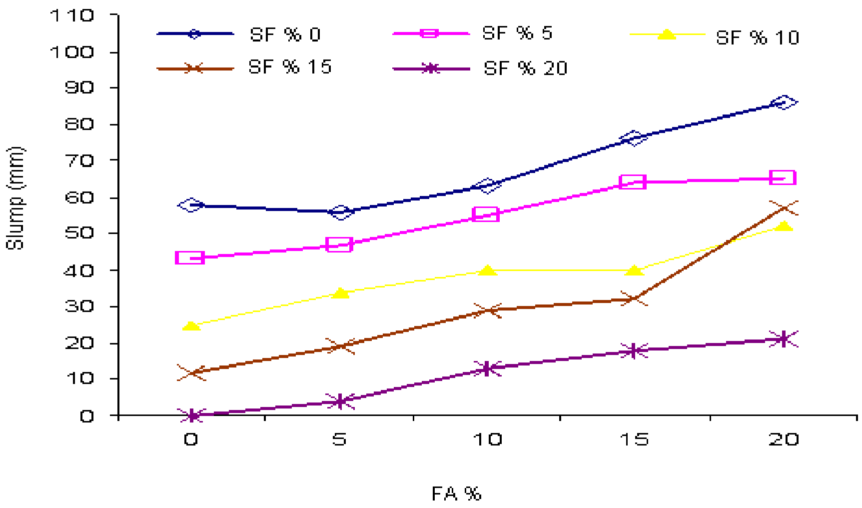

Figure 2. Change in the amount of slump with respect to FA ratio (SF constant).

Table 7. Unit weights of hardened concrete samples.

Concrete code	Average unit weight (gr/cm^3)	Concrete code	Average unit weight (gr/cm^3)	Concrete code	Average unit weight (gr/cm^3)	Concrete code	Average unit weight (gr/cm^3)	Concrete code	Average unit weight (gr/cm^3)
FA0SF0	1.78	FA5SF0	1.77	FA10SF0	1.73	FA15SF0	1.74	FA20SF0	1.75
FA0SF5	1.77	FA5SF5	1.76	FA10SF5	1.8	FA15SF5	1.79	FA20SF5	1.78
FA0SF10	1.77	FA5SF10	1.76	FA10SF10	1.78	FA15SF10	1.8	FA20SF10	1.76
FA0SF15	1.76	FA5SF15	1.76	FA10SF15	1.79	FA15SF15	1.74	FA20SF15	1.77
FA0SF20	1.76	FA5SF20	1.77	FA10SF20	1.76	FA15SF20	1.78	FA20SF20	1.76

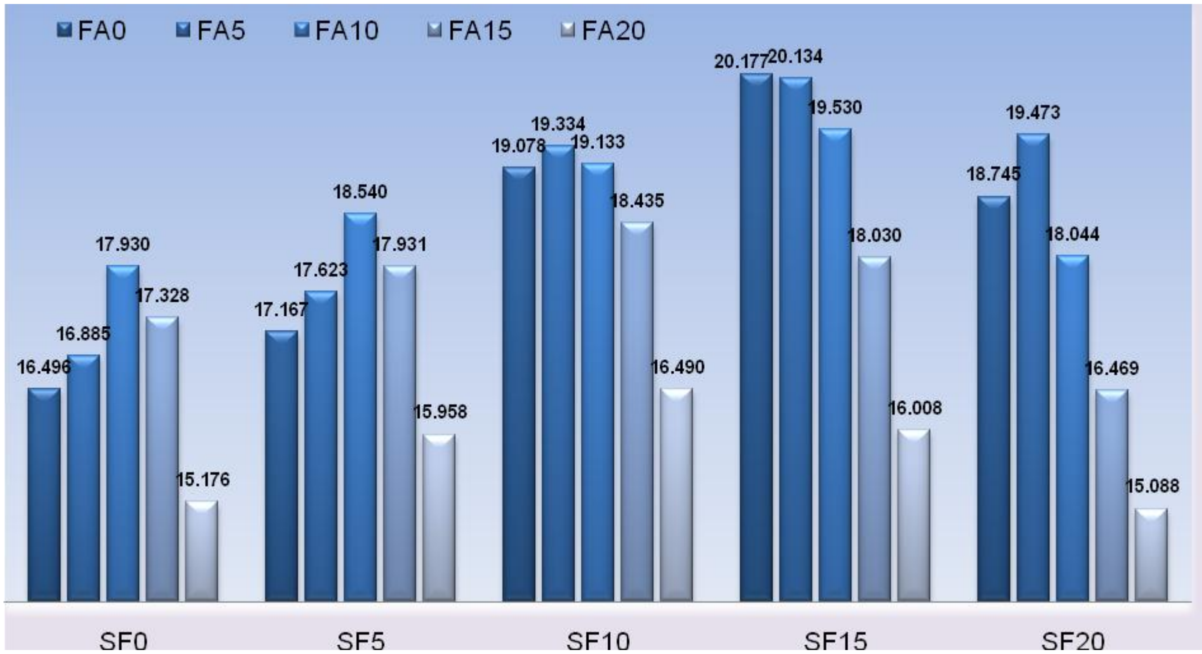

Figure 3. Change in compressive strength of 0-5-10-15 and 20% silica fume substituted series with increasing fly ash.

hardened concrete samples in accordance with TS EN 12390-3. The change in compressive strength of 0-5-10-15 and 20% silica fume substituted series with increasing fly ash is seen in Figure 3. Similarly, the change in compressive strength of 0-5,10-15 and 20% fly ash substituted series with increasing silica fume is seen in groups in Figure 4.

In addition, surface hardness of hardened concrete samples is determined by Schmidt concrete test hammer and ultrasonic measurement is conducted in accordance with ASTM C 597. Surface hardness of concrete samples and ultrasonic measurement readings are given in Figures 5 and 6, respectively.

Variance analysis is conducted in order to determine whether there is a meaningful statistical change in compressive strength or not with a change in the amount of SF substitution when FA is kept constant by 0-5, 10-15 and 20% and similarly with a change in the amount of FA substitution when SF is kept constant by 0-5, 10-15 and 20% (Table 8). Results of the variance analysis yield considerable differences in significance level for all concrete series ($p \leq 0.05$).

In order to determine the groups which cause the difference between the groups in all series, Scheffe

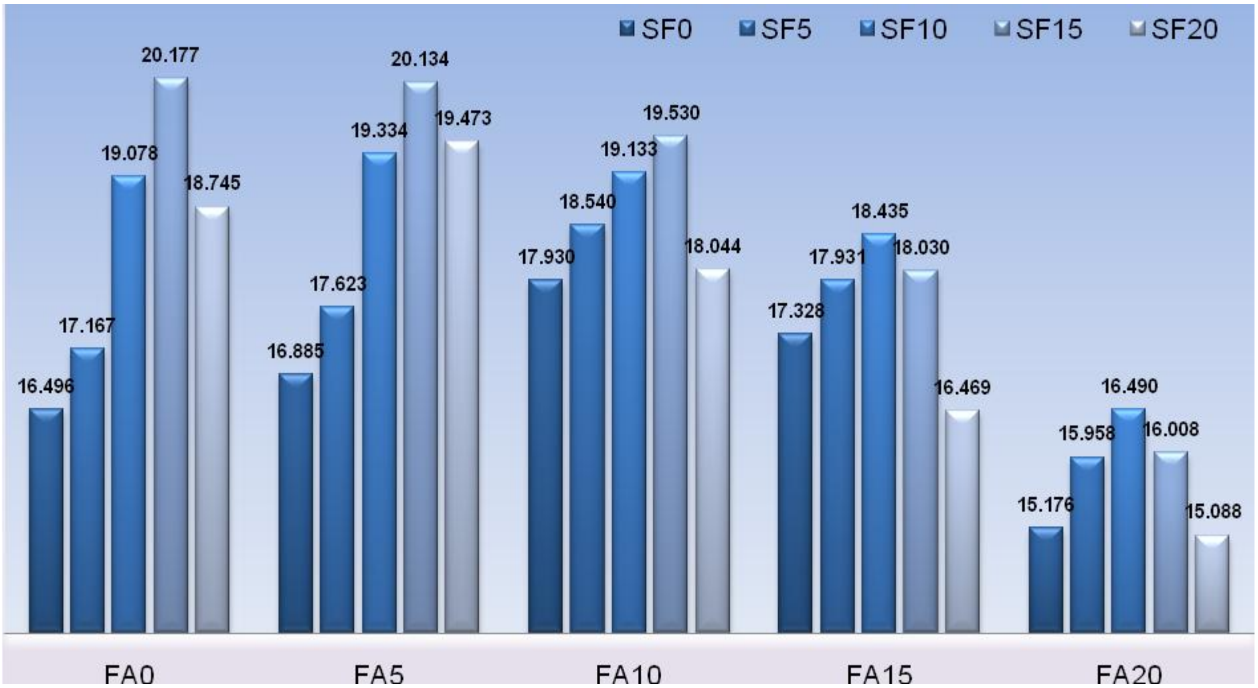

Figure 4. Change in compressive strength of 0- 5-10-15 and 20% fly ash substituted series with increasing silica fume.

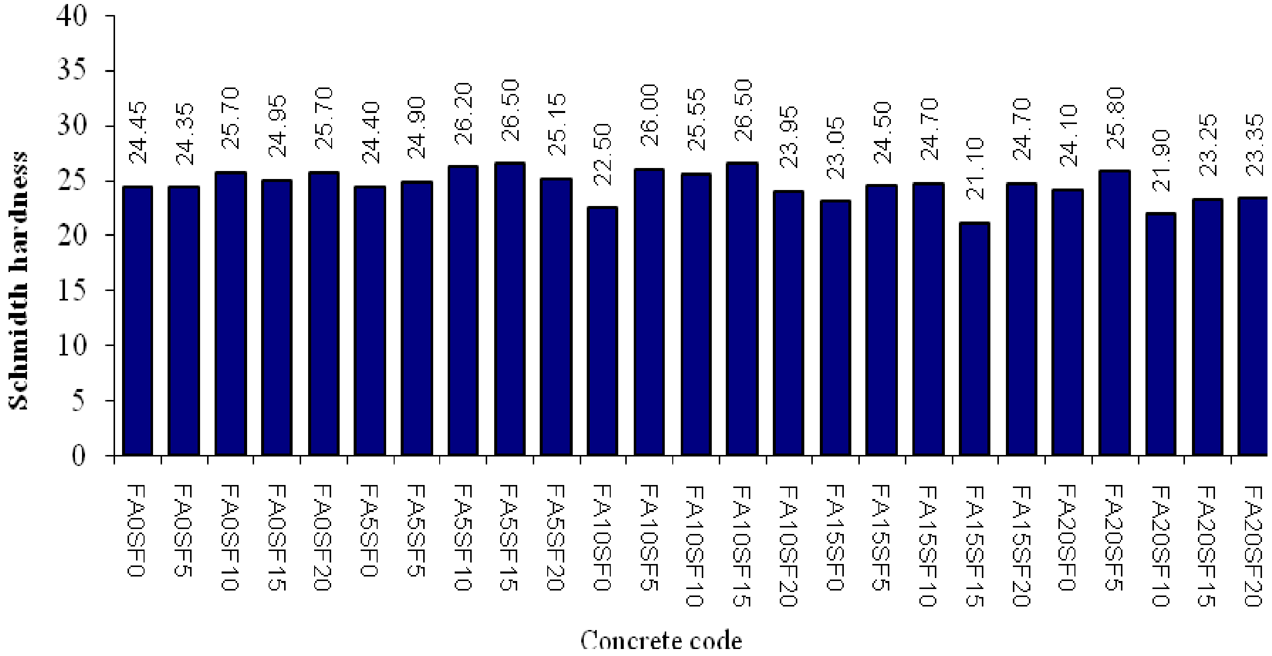

Figure 5. Means of surface hardness readings.

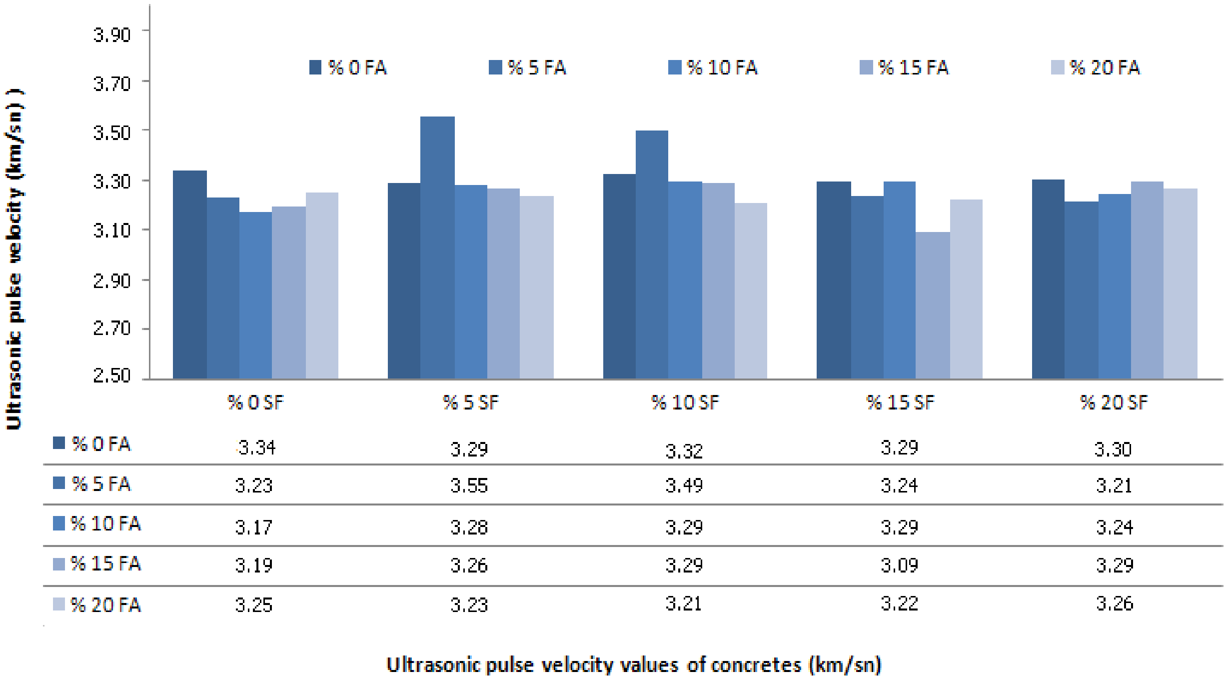

Figure 6. Means of ultrasonic pulse velocity values.

Table 8. Results of variance analysis for all concrete series.

Group	Variance source	Sum of squares	Degrees of freedom	Mean square	F test	Significance level (α)
FA 0 SF 0-5-10-15-20	Between groups Intra-group	35.43528 1.46292	4 15	8.85882 0.09753	90.834	0.000
FA 5 SF 0-5-10-15-20	Between groups Intra-group	30.03039 1.93467	4 15	7.5076 0.12898	58.208	0.000
FA 10 SF 0-5-10-15-20	Between groups Intra-group	7.61866 1.30699	4 15	1.90466 0.08713	21.859	0.000
FA 15 SF 0-5-10-15-20	Between groups Intra-group	9.34494 1.53155	4 15	2.33623 0.1021	22.881	0.000
FA 20 SF 0-5-10-15-20	Between groups Intra-group	5.6918 1.86184	4 15	1.42295 0.12412	11.464	0.000
SF 0 FA 0-5-10-15-20	Between groups Intra-group	17.13872 1.59913	4 15	4.28468 0.10661	40.191	0.000
SF 5 FA 0-5-10-15-20	Between groups Intra-group	15.01825 1.23118	4 15	3.75456 0.08208	45.743	0.000

Table 8. Contd.

SF 10 FA 0-5-10-15-20	Between groups	21.90251	4	5.47563	55.366	0.000
	Intra-group	1.48349	15	0.0989		
SF 15 FA 0-5-10-15-20	Between groups	50.38056	4	12.59514	105.689	0.000
	Intra-group	1.78758	15	0.11917		
SF 20 FA 0-5-10-15-20	Between groups	50.39364	4	12.59841	94.581	0.000
	Intra-group	1.99803	15	0.1332		

Table 9. Scheffe multiple comparison test results for the series with 0% FA and variable SF.

MCT method	SF (%)	N	Difference between the groups = (α) 0.05		
			1	2	3
Scheffe	0	4	16.49600		
	5	4	17.16750		
	20	4		18.74525	
	10	4		19.07775	
	15	4			20.17725

Table 10. Scheffe multiple comparison test results for the series with 5% FA and variable SF.

MCT method	SF (%)	N	Difference between the groups = (α) 0.05	
			1	2
Scheffe	0	4	16.88525	
	5	4	17.62300	
	10	4		19.33350
	20	4		19.47325
	15	4		20.13375

multiple comparison test (MCT) is performed. MCT results for the series with 0% FA and variable SF are given in Table 9.

According to the MCT results, it is seen that 0% SF substituted concrete has the lowest compressive strength of 16.496 MPa, 15% SF substituted concrete has the highest compressive strength of 20.177 MPa and there is no statistical difference in compressive strength in compressive strength between 0-5% and 20-10% SF substituted groups. MCT results for the series with 5% FA and variable SF are given in Table 10.

According to the MC T results, it is seen that 0% SF substituted concrete has the lowest compressive strength of 16.885 MPa, 15% SF substituted concrete has the highest compressive strength of 20.133 MPa, there is no statistical difference in compressive strength between 0 and 5% SF substituted groups as well as between 10-20 and 15% SF substituted groups. MCT results for the series with 10% FA and variable SF are given in Table 11.

According to the MCT results, it is seen that 0% SF substituted concrete has the lowest compressive strength of 17.929 MPa, 15% SF substituted concrete has the highest compressive strength of 19.530 MPa, there is no

Table 11. Scheffe multiple comparison test results for the series with 10% FA and variable SF.

MCT method	SF (%)	N	Difference between the groups = (α) 0.05		
			1	2	3
Scheffe	0	4	17.92975		
	20	4	18.04400		
	5	4	18.54025	18.54025	
	10	4		19.13300	19.13300
	15	4			19.53000

Table 12. Scheffe multiple comparison test results for the series with 15% FA and variable SF.

MCT method	SF (%)	N	Difference between the groups = (α) 0.05		
			1	2	3
Scheffe	20	4	16.46925		
	0	4		17.32850	
	5	4		17.93125	17.93125
	15	4		18.03000	18.03000
	10	4			18.43475

Table 13. Scheffe multiple comparison test results for the series with 20% FA and variable SF.

MCT method	SF (%)	N	Difference between the groups = (α) 0.05		
			1	2	3
Scheffe	20	4	15.08850		
	0	4	15.17650	15.17650	
	5	4	15.95850	15.95850	15.95850
	15	4		16.00750	16.00750
	10	4			16.48950

statistical difference in compressive strength between 0-20 and 5% SF substituted groups similarly between 5 and 10% SF substituted groups as well as 10 and 15% SF substituted groups. MCT results for the series with 15% FA and variable SF are given in Table 12.

According to the MCT results, it is seen that 20% SF substituted concrete has the lowest compressive strength of 16.469 MPa, 10% SF substituted concrete has the highest compressive strength of 18.435 MPa, there is no statistical difference in compressive strength between 0-5 and 15% SF substituted groups as well as between 5-15 and 10% SF substituted groups. MCT results for the series with 20% FA and variable SF are given in Table 13.

According to the MCT results, it is seen that 20% silica fume substituted concrete has the lowest compressive strength of 15.088 MPa, 10% SF substituted concrete has the highest compressive strength of 16.490 MPa, there is no statistical difference in compressive strength between 20-0 and 5% SF substituted groups and there is also no statistical difference in compressive strength between 0-5 and 15% SF substituted groups as well as 5, 15, 10% SF substituted groups. MCT results for the series with 0% SF and variable FA are given in Table 14.

According to the MCT results, it is seen that 20% fly ash substituted concrete has the lowest compressive strength of 15.176 MPa, 10% FA substituted concrete has the highest compressive strength of 17.930 MPa, there is no statistical difference in compressive strength

Table 14. Scheffe multiple comparison test results for the series with 0% SF and variable FA.

MCT method	FA (%)	N	Difference between the groups = (α) 0.05			
			1	2	3	4
Scheffe	20	4	15.17637			
	0	4		16.49586		
	5	4		16.88525	16.88525	
	15	4			17.32848	17.32848
	10	4				17.92971

Table 15. Scheffe multiple comparison test results for the series with 5% SF and variable FA.

MCT method	FA (%)	N	Difference between the groups = (α) 0.05			
			1	2	3	4
Scheffe	20	4	15.95847			
	0	4		17.16745		
	5	4		17.62296	17.62296	
	15	4			17.93122	17.93122
	10	4				18.54029

Table 16. Scheffe multiple comparison test results for the series with 10% SF and variable FA.

MCT method	FA (%)	N	difference between the groups = (α)0 .05		
			1	2	3
Scheffe	20	4	16.48953		
	15	4		18.43480	
	0	4		19.07768	19.07768
	10	4		19.13293	19.13293
	5	4			19.33382

between 0 and 5% with 5 and 15% FA substituted groups as well as between 15 and 10% substituted groups. MCT results for the series with 5% SF and variable FA are given in Table 15.

According to the MCT results, it is seen that 20% fly ash substituted concrete has the lowest compressive strength of 15.959 MPa, 10% FA substituted concrete has the highest compressive strength of 18.540 MPa, there is no statistical difference in compressive strength between 0 and 5% with 5 and 15% FA substituted groups as well as between 15 and 10% substituted groups. MCT results for the series with 10% SF and variable FA is given are Table 16.

According to the MCT results, it is seen that 20% fly ash substituted concrete has the lowest compressive strength of 16.490 MPa, 5% FA substituted concrete has the highest compressive strength of 19.334 MPa and there is no statistical difference in compressive strength between 15-0-10% FA substituted groups as well as between 0-10-5% substituted groups. MCT results for the series with 15% SF and variable FA are given in Table 17.

According to the MCT results, it is seen that 20% fly ash substituted concrete has the lowest compressive strength of 16.007 MPa, 0% FA substituted concrete has the highest compressive strength of 20.177 MPa and there is no statistical difference in compressive strength between 10-5 and 0% FA substituted groups. MCT

Table 17. Scheffe multiple comparison test results for the series with 15% SF and variable FA.

MCT method	FA (%)	N	Difference between the groups = (α) 0.05		
			1	2	3
Scheffe	20	4	16.00786		
	15	4		18.03011	
	10	4			19.53017
	5	4			20.13376
	0	4			20.17739

Table 18. Scheffe multiple comparison test results for the series with 20% SF and variable FA.

MCT method	FA (%)	N	Difference between the groups = (α) 0.05			
			1	2	3	4
Scheffe	20	4	15.088			
	15	4		16.469		
	10	4			18.044	
	0	4			18.745	18.745
	5	4				19.473

results for the series with 20% SF and variable FA are given in Table 18.

According to the MCT results, it is seen that 20% fly ash substituted concrete has the lowest compressive strength of 15.088 MPa, 5% FA substituted concrete has the highest compressive strength of 19.473 MPa and there is no statistical difference in compressive strength between 10-0% FA substituted groups as well as between 0-5% substituted groups.

Comments on the results

In 0-5 and 10% fly ash substituted concrete series, compressive strength of concrete is increased for the amount of silica fume substitution up to 15% and is decreased for amounts above 15%. In 15 and 20% fly ash substituted concrete series, compressive strength of concrete is increased for the amount of silica fume substitution up to 10% and is decreased for amounts above 10%. In 0 and 5% silica fume substituted concrete series, compressive strength of concrete is increased for the amount of fly ash substitution up to 10% and is decreased for amounts above 10%. In 10% silica fume substituted concrete series, compressive strength of concrete is increased for the amount of fly ash substitution up to 5% and is decreased for amounts above 5%. In 15% silica fume substituted concrete series, compressive strength of concrete is decreased continuously inversely proportional to the increase in the amount of fly ash substitution. In 20% silica fume substituted concrete series, compressive strength of concrete is increased when the amount of fly ash substitution is 5% and is decreased in all series with fly ash substitution above 5% inversely proportional to the increase in the amount of fly ash substitution. When the study is considered from the point of surface hardness and ultrasonic transmission rate, No meaningful relationship is observed in concrete series in terms of surface hardness and ultrasonic transmission rate. The reason is thought to be the cellular structure of pumice aggregate used in the concrete and possible distribution of its cellular structure in different forms.

Conclusions

When the study is considered from the point of fresh concrete properties, in terms of fresh concrete unit weights, in all concrete series in which fly ash is kept constant and the amount of silica fume substitution is increased except for 15 and 20% fly ash substituted series, fresh concrete unit weight is increased when the amount of silica fume substitution is increased from 0 to 5%, is decreased when the amount of silica fume substitution is increased from 5 to 10%, remains unchanged when the amount of silica fume substitution is increased from 10 to 15% and is decreased when the amount of silica fume substitution is increased to 20%. In 15% fly ash substituted series, fresh concrete unit weight has a tendency towards an increase for all substitution amounts, except for 15 to 20% transition, depending on the amount of silica fume substitution. In 20% fly ash substituted series, fresh concrete unit weight is increased when the amount of silica fume substitution is increased from 0 to 5%, is decreased when the amount of silica fume substitution is increased from 5 to 10% and remains unchanged when the amount of silica fume substitution is above 10%. Considering the results it is interpreted that there does not exist a meaningful relationship between fresh concrete unit weight and the amount of fly ash and silica fume substitution. In terms of fresh concrete workability, except for 20% FA substituted and variable SF series slump readings are decreased depending on the amount of silica fume substitution. In 20% FA substituted series, slump readings are increased only when the amount of silica fume substitution is changed from 10 to 15%. Except for 0% silica fume substituted and variable fly ash series slump readings are increased depending on the amount of fly ash substitution. In 0% silica fume substituted series, slump readings are decreased only when the amount of fly ash substitution is changed from 0 to 5%.

The results are interpreted as follows; an increase in the amount of silica fume substitution affects fresh concrete workability in a negative manner whereas an increase in the amount of fly ash substitution increases fresh concrete workability. When the study is considered from the point of hardened concrete properties, in terms of hardened concrete unit weights, in all concrete series, hardened concrete unit weight readings yield different ranges and no meaningful relationship is observed between the series. In terms of hardened concrete compressive strength, in concrete series without fly ash, compressive strengths of 16.496 MPa -17.167 MPa -19.078 MPa and 20.177 MPa are obtained respectively corresponding to the amount of silica fume substitution from 0 to 15%. The compressive strength drops by 7.1% and takes a value of 18.745 MPa when the amount of silica fume substitution is increased from 15 to 20%. In 5% fly ash substituted concrete series, compressive strengths of 16.885 MPa -17.623 MPa -19.334 MPa and20.134 MPa are obtained respectively corresponding to the amount of silica fume substitution from 0 to 15%. The compressive strength drops by 3.3% and takes a value of 19.473 MPa when the amount of silica fume substitution is increased from 15 to 20%. In 10% fly ash substituted concrete series, compressive strengths of 17.930 MPa -18.540 MPa -19.133 MPa and 19.530 MPa are obtained respectively corresponding to the amount of silica fume substitution from 0 to 15%. The compressive strength drops by 7.6% and takes a value of 18.044 MPa when the amount of silica fume substitution is increased from 15 to 20%. In 15% fly ash substituted concrete series, compressive strengths of 17.329 MPa -17.931 MPa and 18.435 MPa are obtained respectively corresponding to the amount of silica fume substitution from 0 to 10%. The compressive strength drops by 2.2% and takes a value of 18.030 MPa when the amount of silica fume substitution is increased from 10 to 15%. It establishes similar behavior when the amount of silica fume is increased from 15 to 20% and takes a value of 16.469 MPa. In 20% fly ash substituted concrete series, compressive strength of 15.176 MPa -15.959 MPa and 16.490 MPa are obtained respectively corresponding to the amount of silica fume substitution from 0 to 10%. The compressive strength drops by 2.9% and takes a value of 16.007 MPa when the amount of silica fume substitution is increased from 10 to 15%. It establishes similar behavior when the amount of silica fume is increased from 15 to 20% and takes a value of 15.088 MPa.

In concrete series without silica fume, compressive strength of 16.496 MPa -16.885 MPa and 17.930 MPa are obtained respectively corresponding to the amount of fly ash substitution from 0 to 10%. The compressive strength drops by 3.4% and takes a value of 17.329 MPa when the amount of fly ash substitution is increased from 10 to 15%. It establishes similar behavior when the amount of fly ash is increased from 15 to 20% and takes a value of 15.176 MPa. In 5% silica fume substituted concrete series, compressive strength of 17.168 MPa -17.623 MPa and 18.54 MPa are obtained respectively corresponding to the amount of fly ash substitution from 0 to 10%. The compressive strength drops by 3.3% and takes a value of 17.931 MPa when the amount of fly ash substitution is increased from 10 to 15%. It establishes similar behavior when the amount of fly ash is increased from 15 to 20% and takes a value of 15.959 MPa. In 10% silica fume substituted concrete series, compressive strength is increased only at the transition from 0 to 5% depending on the amount of fly ash substitution and increases from 19.078 MPa to 19.334 MPa. A decrease in compressive strength is observed for all remaining amounts of fly ash substitution. Compressive strength decreases to 19.133 MPa for 10% fly ash substitution, 18.435 MPa for 15% fly ash substitution, 16.49 MPa for 20% fly ash substitution. In 15% silica fume substituted concrete series, compressive strength is decreased for all amounts of fly ash substitution. Compressive strength decreases to 20.177 MPa for 0% fly ash substitution, 20.134 MPa for 5% fly ash substitution, 19.53 MPa for 10% fly ash substitution, 18.03 MPa for 15% fly ash substitution, 16.007 MPa for 20% fly ash substitution. In 20% silica fume substituted concrete series, compressive strength is increased only at the transition from 0 to 5% depending on the amount of fly ash substitution and increases from 18.745 MPa to 19.473 MPa. A decrease in compressive strength is observed for all remaining amounts of fly ash substitution. Compressive strength decreases to 18.044 MPa for 10% fly ash substitution, 16.469 MPa for 15% fly ash substitution, 15.088 MPa for 20% fly ash substitution.

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REFERENCES

Beycioglu A (2008). Modelling the effects of industrial wastes on properties of lightweight concrete by fuzzy logic method. Süleyman Demirel University. Grad. School Nat. Appl. Sci., 7: 12.

Ke Y, Beaucour AL, Ortola S, Dumontet H, Cabrillac R (2009). Influence of volume fraction and characteristics of lightweight aggregates on the mechanical properties of concrete. Construc. Build. Mat., 23: 2821–2828.

Kocak Y (2010). A Study On The Effect Of Fly Ash And Silica Fume Substituted Cement Paste And Mortars. Sci. Res. Essays, 5(9): 990-998.

Malhotra VM, Mehta PK (2002). High Performance, High Volume Fly Ash Concrete Supplementary Cementing Materials for Sustainable Development Inc., p. 101.

Mouli M, Khelafi H (2008). Performance characteristics of lightweight aggregate concrete containing natural pozzolan. Build. Environ., 43: 31-36.

Shui Z, Zhang R, Chen W, Xuan D (2010). Effects of mineral admixtures on the thermal expansion properties of hardened cement paste. Construc. Build. Mater., 24(9): 1761-1767.

Subaşı S (2009). The effects of using fly ash on high strength lightweight concrete produced with expanded clay aggregate. Sci. Res. Essay, 4(4): 275-288.

TS EN 12350-2 (2009). Concrete - fresh concrete tests - Part 2: Slump (slump) test. BS EN 12350-2.

TS 2941 (1991). Fresh Concrete Unit Weight, Yield and Air Volume Determination of the Weight Method. Lightweight Concrete, ACI Mater. J., 88(3): 240-247.

TS EN 12390-3 (2001). Concrete - Hardened concrete tests - Part 3: Determination of compressive strength of test specimens. The European Standard EN 12390-3.

ASTM C597 - 09 (2002). Standard Test Method for Pulse Velocity Through Concrete, BS EN 12390-3.