INVESTIGATION OF MECHANICAL PROPERTIES OF MORTARS MADE OF CLASSLESS AFSIN-ELBISTAN FLY ASH AND GLASS POWDERS

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ABSTRACT

This study aims at evaluating the classless Afşin-Elbistan fly ash. Therefore, Classless Afsin-Elbistan fly ash and waste granulated glass have been mixed at certain rates. This mixture has produced mortar samples by substituting with different percentages instead of cement. 3-7-28 daily bending strengths, setting durations, volume expansion experiments of the samples produced have been made. As a result of study, it has been determined that as the contribution of fly ash and granulated glass increases, the setting durations increase. Besides, ash can be obtained in accordance with the standards by the use of 30% of the mixture of fly ash and granulated glass. It has been founded that many properties of the mortars produced are higher than the values to be obtained from the class ashes

Keywords: Fly Ash, Granulated Glass, Setting Duration, Strength.

INTRODUCTION

Very thin particles in thermal power station are collected in electro filters by carrying flue draught. These ashes are entrained with flue ashes. Then, the ashes contact with air and they achieve pozzolanic features as result of rapid cooling. The diameters of these ashes having generally a spherical structure are between 1-100 micron. In order to earn both for economy and for environment by evaluating waste fly ashes of thermal power stations, works have been carried out. In our country, millions of tons of fly ash is emerging as a by-product of thermal power stations. A small portion of these amounts is used in the cement production and dam injections and brick production. However, fly ashes that are a industrial waste have many different and common usage areas in many countries(1).The fly ashes that are pozzolanic substance was started to be used as additive in concrete in 1950s in North American countries and continued by expanding after the energy crisis in 1970s (2).The fly ashes whose production amounts have reached large measures in parallel with the energy needs have many potential usage areas such as in agriculture, in chemical industry, soil stabilization and in the production of various structure material (3). Less than 25%of the fly ash produced annually in the world is evaluated. However, more than 95% of the total fly ash produced is used in Germany, Holland and Belgium and about 50% is used in England. It is seen that USA and China where fly ash is produced in large amounts use approximately 32% and 40% of these produced ash respectively (4).In accordance with 1990 data in Turkey, the utilization rate of fly ash is less than 1%(5).

The flu ashes are divided into two classes including F and C according to ASTM C618'c.The F class fly ashes are obtained as result of burning anthracite coal and they are entitled as low ash lime since they include CaO less than 10 %.Since free lime has not been founded within these ashes, they don't have self-hardening property and but they show hardening by reacting

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with lime in aqueous medium. Puzzolanic reactions are very slow in normal conditions (6-89. C Class fly ashes are obtained as result of burning lignite coal, they keep more than 10% CaO within and therefore they are defined as high-lime fly ash.

C Class fly ashes have the self-cemented feature due to free lime. In Accordance with ASTM C618'c, since the fly ash of Afşin-Elbistan Thermal Power station is classless, it can't be used in cement and concrete production. In one study, a large amount of samples of mortar and concrete including 10% and 20% AEFA are equivalent to the reference samples or it has been specified that close compressive, tensile and abrasion resistance, carbonation, vacancy rate and capillary have given water absorption coefficient. It has been suggested that AEFA can be used as cement and concrete additive between 10% and 20% (9).In this study, primarily the mentioned ash has been classified by using granulated glass at certain rates by the Afsin-Elbistan Thermal Ash. Then, the cement produced by (AEFA-GG) with the class ash obtained has been searched if it can be used in the concrete production or not.

MATERIAL AND METHOD

Material

The materials used in the study; Afşin-Elbistan Fly Ash (AEFA) nonconforming to CEM 1 (PÇ 42,5), TS 639 Standard Rilem Sand and Tekirdağ glass dust (GD)

Cement

CEM 1 (PÇ 42,5) used as control cement has been supplied from Kahramanmaraş Cement Industry).

Fly Ash

Classless Fly Ash has been supplied from Afsin Elbistan Thermal Power Stations.

Standard Rilem Sand

The Standard soil on the size specified at TS 819(10) has been used in the study.

Method

The combinations of the Afsin Elbistan fly ash (AEFA) and glass dust (GD) in various properties and the mentioned ash have been tried to make them the class. Turkey is one of the respectable countries in glass industry. As the result of increasing consumption together with the production, the problem of waste glass has emerged significantly. Leaving the glass which is fragile and sharp material to the nature as a waste is very dangerous and harmful to health. The destruction to be constituted in the environment cannot be removed for long years. Glass is made of soil that has much silicium material (SiO_2). Since SiO rate is high and by putting it in Classless Afsin Elbistan Fly Ash at various rates, it has been used in mortar samples by making it class fly ash. The purpose of this study is to investigate the effect of cement strength by mixing fly ash that is a artificial puzzolans with waste granulated glass at various proportions. All the experiments applied in the research have been made based on the standards of some developed countries and Turkish Standards. These experiments consider normal consistency water rates of cement paste, the start and expiation durations of the setting and determinations of volume expansion TS EN196-3(11), flexural and compressive strengths TS EN 196-1 (12), and various literature studies.

The studies of the experiments have been carried out in Gaziantep University Faculty of Engineering and Architecture concrete laboratory, in Kahramanmaraş Cement Industry Physics and Concrete Laboratory. The following tests have been made in these studies.

AEFA-GD Mixture and Cement Production

Cement is produced by clinker and other additive materials and by grinding it separately. Clinker and ground blast furnace slag (GBFS) are at different grindability and exhibit different kinetic behaviours (13). It has been specified that specific grinding energy required in together grinding is higher, GBFS cements grinded together in the same fineness have given low strength in comparison with the cements obtained by mixture and separate grinding (14). It is known that, in low rate GBFS included cements, in the beginning, the effect of GBFS fineness is lower, the effect of clinker fineness is more evident. Generally, it has been specified that the hardening of the GBFS cement is slower than Portland cement in the first 28 days, however, then, its 12 months strengths with its strength plus can come up even the Portland cement strength (15). Normally, clinker is softer when Portland cement clinkers and GBFS are grinded together, even though its fineness in comparison with GBFS is higher, Portland cement and GBFS have been grinded separately, they have been mixed with GBFS Portland cement grinded in five different fineness. One Portland cement and five GBFS cement concrete, same water / cement rate and same type aggregates have been used. It has been seen that there is a good correlation between the strength of the concrete and the fineness of GBFS grinded at the end of experimental studies, as the fineness of grinded GBFS increases, the compression strength of concrete increases, too (16). It has been determined that the comparison of grinding Natural puzzolans and GBFS separately and together has been made, and natural pozzolans are softer, are grinded easier, whereas GBFS is harder and less grinded (17). Very finely grinded limestone, GBFS together with Portland cement clinkers and grinding the limestone with intensive and careful control develop the distribution of grain size of cement to be varied in fine range (18).In the event that cement and mineral additives are grinded together in mill, it has been seen that more homogeny cement has been obtained (19-21). AEFA and GG % combination rates of the additives obtained in this work have been given at Table 1.The chemical, mineralogical and physical features of the materials used in the work has been given at Table 2.

Table 1. Mix proportion

Samples no	Aditives	
	AEFA	Glass dust (GD)
Referans (R)	-	-
S_1	95	5
S_2	90	10
S_3	85	15
S_4	80	20
S_5	70	30
S_6	60	40
S_7	50	50

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Table 2. Chemical content of AEFA ve AEFA-GD mixes

Samples	Componenet								Flay ash class	
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	Loss ignigation	S+A+F	Class
AEFA	18.27	9.16	3.26	53.44	1.75	11.4	0.19	2.12	30.69	classless
S_1	44.7	15.9	7.8	17.6	2.8	4.2	1.48		68.4	C
S_2	46.6	15.2	7.3	16.5	2.9	4.3	2.26		69.1	C
S_3	49.7	13.8	6.7	15.6	3.1	3.9	3.69		70.2	F
S_4	52.2	13	6	15.2	3.3	3.6	4.70		71.2	F
S_5	54.4	12.8	6.8	15.8	3.4	3.6	5.32		74.0	F
S_6	55.7	10.8	5.2	14.5	3.4	2.9	6.58		71.7	F
S_7	58.0	9.2	4.5	14.1	3.6	2.5	7.81		71.7	F
TS 639	F				<5	<5		<10	>70	
ASTM C 618	F					<5		<6	>70	
	C					<5		<6	>50	

Fineness

The kind of cement and features are one of the most important features affecting the concrete strength. The effect of cement features on the strength can be explained highly by cruising of hydration quickly and slowly. On condition that hydration develops very quickly, the strength of cement get great values for a short time. The increase of the cement fineness causes increase of the specific area. The strength of binding agent accelerates with increasing of fineness and therefore, increases are seen in the 3, 7, 28, 90 and 180 day strengths of cement, however the effect of fineness on last impact strength are not seen more in terms of practice (22).The substituting rates instead of cement of the additives obtained by the mixtures of AEFA and GG has been given at table 3. Mortar samples have been produced by the new cement produced. Afsin-Elbistan fly ash and granulated glass mixture (AEFA –GG) have been mixed for 30 minutes in iron ball mill and the homogeneity of the cement has been provided.

Table 3. Mix proportion and its Blaine values

Samples	Addition system and its ratio	Blaine (cm^2/g)
R	%100 CEM-I + 0 % AEFA-GD	4101
S_1	%95 CEM-I + 5 % AEFA-GD	4490
S_2	%90 CEM-I + 10 % AEFA-GD	4760
S_3	%85 CEM-I + 15 % AEFA-GD	4764
S_4	%80 CEM-I + 20 % AEFA-GD	4966
S_5	%70 CEM-I + 30 % AEFA-GD	5144
S_6	%60 CEM-I + 40 % AEFA-GD	5135
S_7	%50 CEM-I + 50 % AEFA-GD	5057

Setting Time
The setting time of the produced pasties and mortars have been made in accordance with standards.

Volume Expansions
Le Chatelier tool given at the standard for determining volume expansion has been used. An experiment has been made with the rest of the paste prepared for determining the setting durations.

Table 4. Ingredient mortar mixtures (g)

Samples	Cement	AEFA-GD	Rilem sand	Water
R	450	0	1350	225
S_1	427,5	22,5	1350	225
S_2	405	45	1350	225
S_3	382,5	67,5	1350	225
S_4	360	90	1350	225
S_5	315	135	1350	225
S_6	270	180	1350	225
S_7	225	225	1350	225

The Production of Mortar Samples
40x40x160 mm prism moulds at the size of standards of TS EN have been used.. For mortar samples, the mixture of Afsin Elbistan fly ash and granulated glass (AEFA-GD), cement, soil and the mass ratios of water have been given at Table4.

Flexural Strength
3-7-28 day bending strengths of the mortars produced according to TS EN 196-1have been found.

Compressive Strength
3-7-28 day compressive strengths of the mortars produced according to TS EN 196-1 1 have been found. At the end of compressive test, the arithmetical mean of the 6 results coming from 3 prisms has been taken.

RESULTS AND DISCUSSION

Fineness

The mixture of Afsin-Elbistan Fly ash and granulated glass (AEFA-GD) has been made for 30 minutes and the homogeneity of the cement has been provided. As it can be seen at Table 3, as long as the rate of AEFA-GD rate increases up to 30 %, the fineness value of the cement increases, if there is more contribution than this rate, the fineness has decreased. This situation can be explained by particle size of granulated glass.

Setting Time

The setting durations of the mortar have been given at Figure 1.The results of the experiments stayed between the limit values of the standards (TS10156).As the contribution rate increases, setting duration decreases. However, both the starting and expiration period of the reference sample has been found low in comparison with others. The setting starting and expiration periods of the mortars doped Afsin-Elbistan Fly ash and granulated glass being longer is the general character of puzzolans.

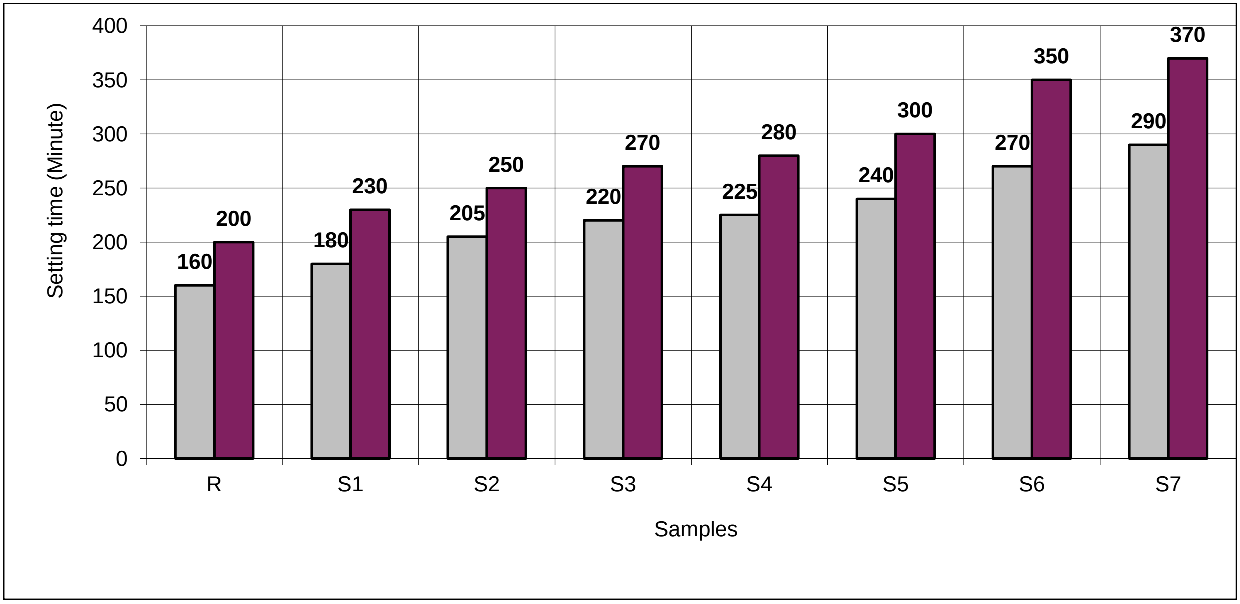

Figure 1. Setting time of samples

Volume Expansions

The volume expansion amounts of the pastes produced by AEFA –GD have been given at Figure 2. None of the samples including the reference hasn't shown any expansion above the limit value specified by the Standard. On the contrary, this value is average around 1 mm. All the available volumetric expansion values have fulfilled the condition to be 10 mm foreseen at TS EN 196-3 (23).Crystal MgO and calcium sulphate are the main factors affecting the excessive expansion of the cement pastes(24).In this context, it has been seen that fly ashes used in the research have decreased the amounts of expansion of the cement pastes a little(25).These results have shown that the mortars doped Afsin-Elbistan fly ash and granulated glass will not bring about an expansion over the value foreseen by the standard. Besides, the volume expansion almost close to zero has been determined in N1 and N2 samples. It has been understood that the found values in accordance with TS EN 196-3 has been suitable.

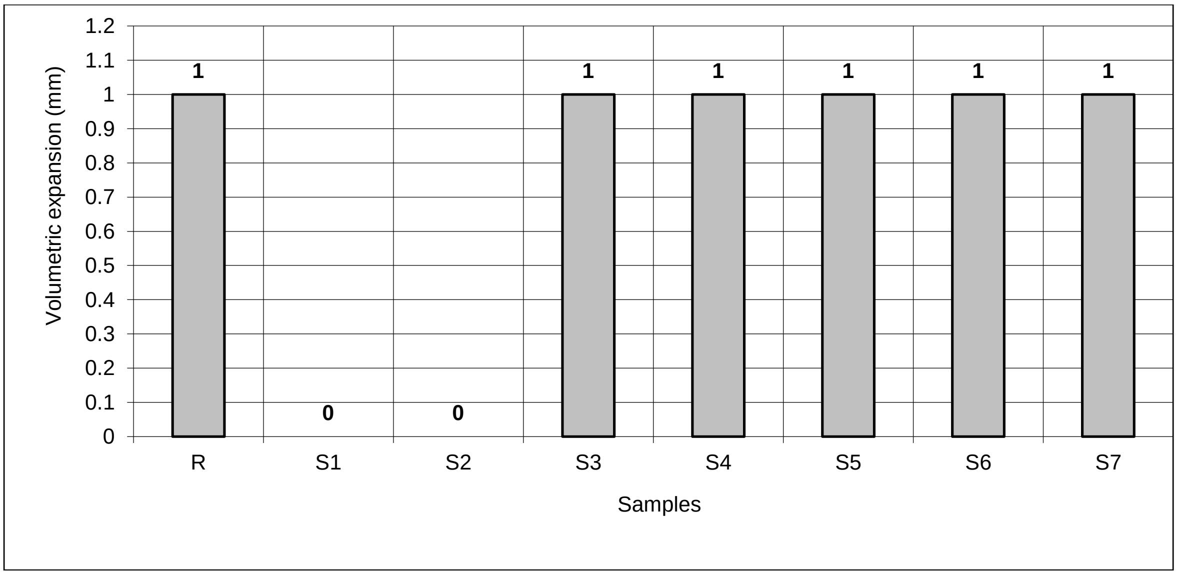

Figure 2. Volumetric expansion of samples

Flexural Strengths

3,7, and 28-day flexural strengths of the mortars in accordance with the specified rules at TS EN 196-1has been given at Figure 3-5. While the 3-day flexural strengths of the samples have increased up to the level of 15 %, then it has fallen substantially. The flexural strength of N3 sample doped 15 % AEFA-GD has been found bigger than the reference sample. On the other hand, the bending strength of this sample has been found about 2,2 times bigger than the bending strength of the N7 sample doped 50 % AEFA-GD .

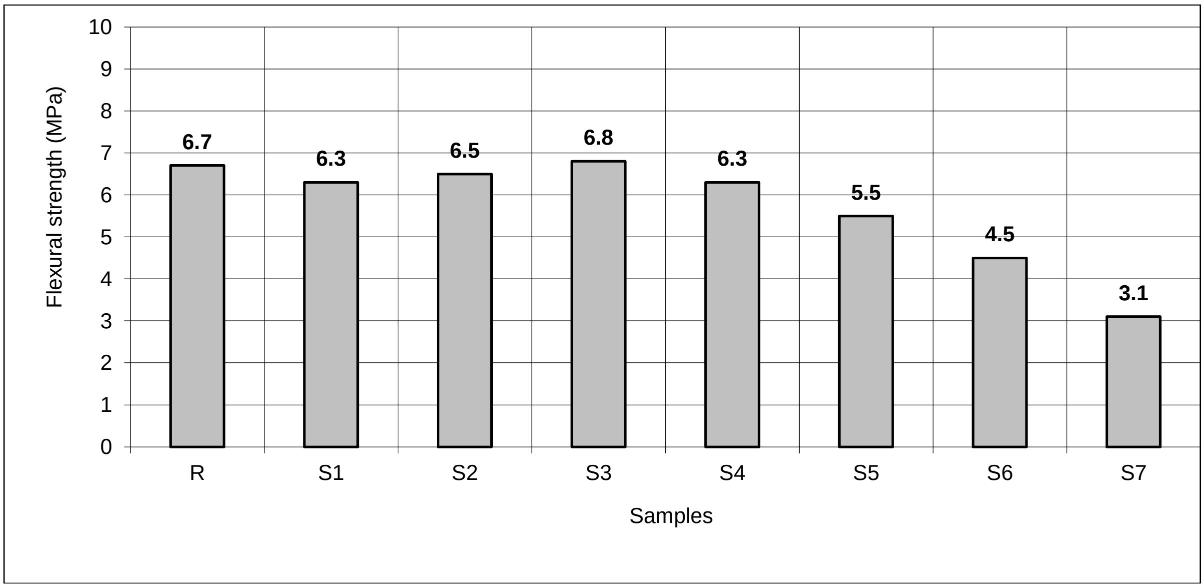

Figure 3. 3-days flexural strength of the samples

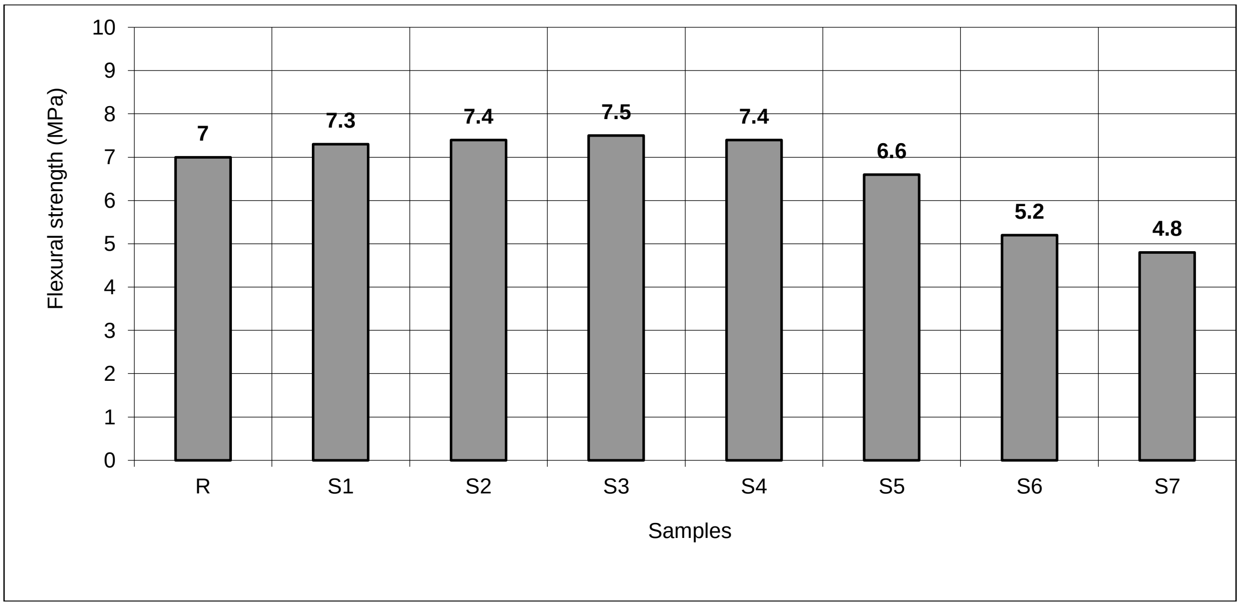

Figure 4. 7-days flexural strength of the samples

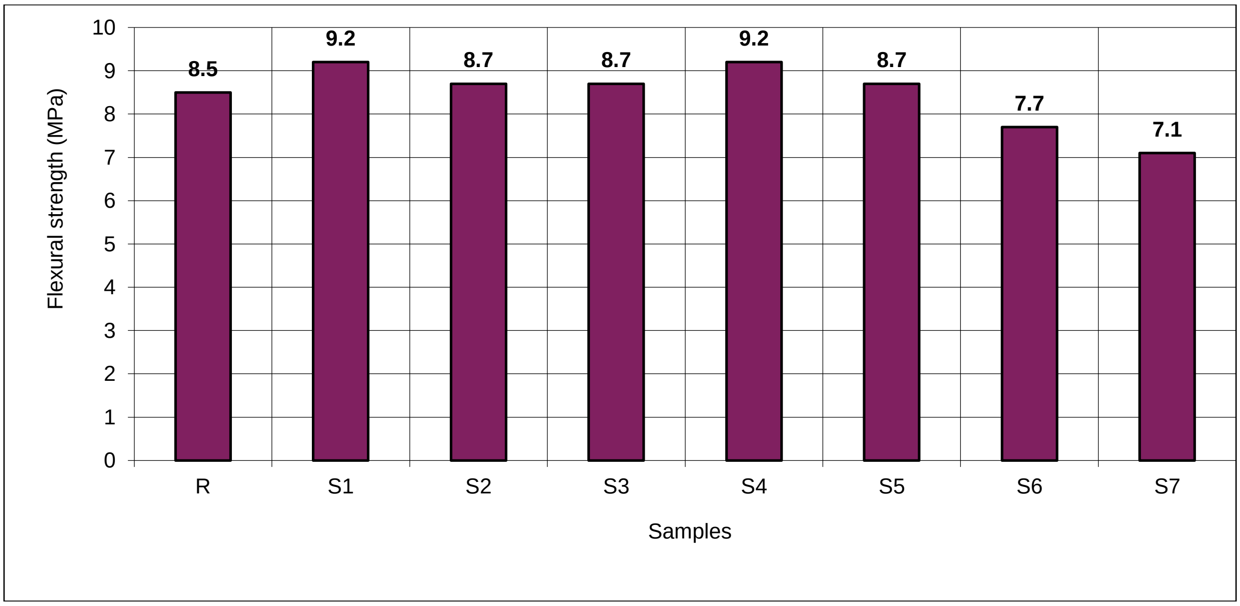

Figure 5. 28-days flexural strength of the samples

While the 7 day- flexural strengths of the samples increase up to 20 % level of the dope, then it has decreased. The flexural strengths of the samples doped 5%,10%,15%, and 20% AEFA–GD have been found bigger than the reference sample. The flexural strength of N3 sample doped 15 % AEFA-GD has been found 9,3 % bigger than the bending strength of the reference sample. On the other hand, the flexural strengths of the samples doped more than 20 % have been fallen. The flexural strength of N3 sample has been found 35 % bigger than the flexural strength of the sample doped 50% AEFA-GD.28 flexural strengths of the samples doped 5%, 10 %, 15%, and 20% and 30 % AEFA-GD of the samples have been found higher than the flexural strength of reference sample. The flexural strength of the samples doped AEA-GD having the highest flexural strength in this group has been found 9% bigger than the flexural strength of the reference sample. However, even the flexural strength of the sample doped 50% has been found higher than the limit value foreseen by the standards

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The optimum contribution rate from these results have been seen as 30%.After this rate, decreasing of the bending strengths somewhat can be explained by the micro structure of the glass. Because, as well as glass is an amorphous material in essence, it shows fairly brittle behaviour.

Compressive Strengths

The 3, 7 and 28-day compressive strengths of the samples have been given at Figure 6-8. The 3 day bending strengths of the samples have been found bigger than the reference sample of the compressive strength of the sample doped 5 % . In more doped rates than these doped rates, the strength of the compressive has reduced significantly. While 7 day compressive strengths of the samples increase up to 20 % dope level, then they have reduced. The compressive strengths of the samples doped 5%, 10% , 15% and 20% AEFA-GD have been found bigger than reference sample. The compressive strength of N1 sample doped 5 % AEFA-GD has been found 9 % bigger than compressive strength of the reference sample. On the other hand, the compressive strength of this sample has been found 1,83 times than the compressive strength of the sample doped 50 % AEFA-GD.

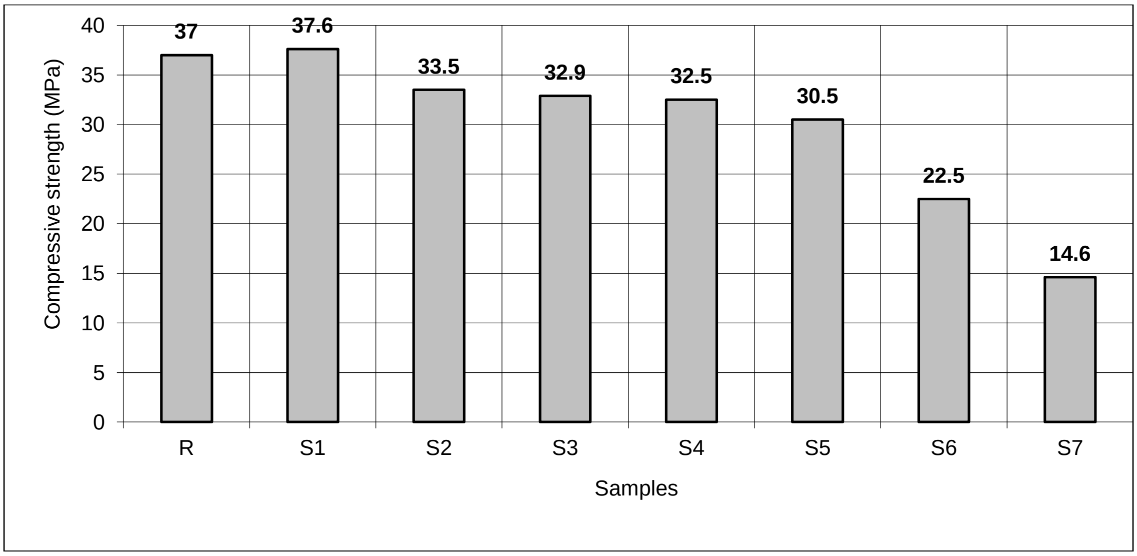

Figure 6. 3-days Compressive strength of the samples

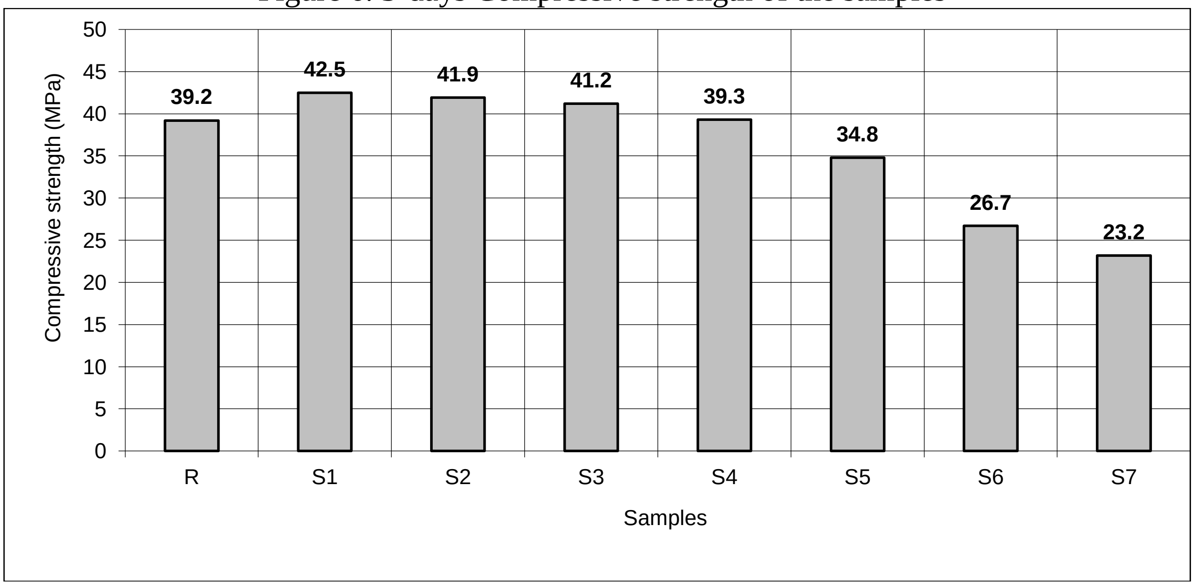

Figure 7. 7- days Compressive strength of the samples

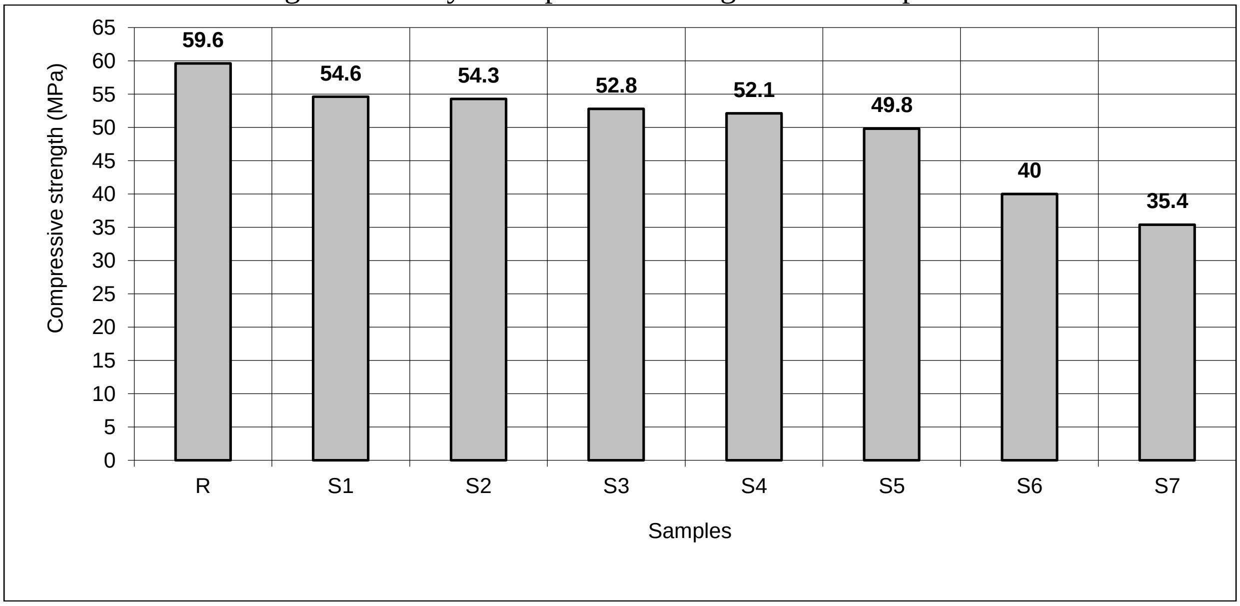

Figure 8. 28-days Compressive strength of the samples

The compressive strength of reference sample has been found bigger than the compressive strengths of all doped samples. However, the compressive strengths obtained up to 30% dope level have been found higher than the values foreseen by the standards.

The optimum dope rate from these results has been seen as 30 %. Generally, on condition that puzzolans are used after a certain dope level, it is known that it causes the compressive strength of the samples to be reduced. When evaluating both bending and compressive strengths together, it can be said that optimum dopes are at about 20% in fly ashes. Literature supports this situation, too.

CONCLUSION

Overall results obtained in the study are listed below.

1. In 3 and 7 day bending strengths, the samples containing 15 % AEFA-GD have shown the most strength
2. 28-day bending strengths of the samples containing 20 %AUFA-GD have been found the highest. This situation can be explained by having high puzzolanic feature of the new class ash
3. 3 and 7 day compressive strengths of the mixture containing 5 %AEFA-GD have been found the highest.
4. In 28 day compressive strengths of the samples containing 5%,10 %,15% 20%,30%, 40%, 50% AEFA–GD have been found higher than compressive strengths of reference samples. The 28 day compressive strengths of some samples have exceeded the 42,5 MPA values.
5. The starting and expiration periods of the setting have changed with the increase of dope rate. Based on the increase of additive material, the starting and expiration periods of the setting have increased. The setting period of the sample doped 50 % is twice of the setting period of the reference sample

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6. Volume expansion has been found zero mm in the mixtures containing 5 % and 10% AEFA-GD, other samples have been found 1 mm. This rate is at the same value with the reference sample.
7. As the increase of the dope of AEFA–GD, the mixture water requirement of the mortars has increased somewhat.
8. The use of fly ashes providing both required strength and economical and environment benefits together with granulated glass is an issue worth investigating.

When classless Afsin-Elbistan fly ash is used at certain proportions with granulated glass, it can be gained to economy as class fly ash.

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REFERENCES

1. Kılınckale M.F., Uçucu Küllü Çimento Üretiminde Uçucu Külün Öğütme Şeklinin Çimento Üzerinde Etkisi, Endüstriyel Atıkların İnşaat Sektöründe Kullanılması Bildiriler Kitabı, TMMOB yayını, 172 s, Ankara, 1995 (In Turkish).
2. Baradan B., Yapı Malzemesi 2, Dokuz Eylül Üniversitesi, Mühendislik Fakültesi Basım Ünitesi, Genişletilmiş Üçüncü Baskı, s. 149, İzmir, 1994(In Turkish).
3. Tokyay, M., Traslı Çimento Nedir? Ne Değildir?, TMMOB İnşaat Mühendisleri Odası, 12-15 Aralık, Ankara, 1994 (In Turkish).
4. Binici H, Çağatay İ.H, Kaplan H, Birlikte ve Ayrı Ayrı Öğütülen Kompoze Çimentonun Özellikleri, KSÜ Fen ve Mühendislik Dergisi 10 (2007) 59–65(In Turkish).
5. PK Mehta., 1986, Concrete, Structure, Properties, and Materials, Prentice-Hall, New Jersey.
6. Alkaya D, Erken A, Alyanak T, Inançlı G. 2002, Uçucu küllerin toprak sanayinde kullanılabilirliği, ll. Uluslararası Pişmiş Toprak Sempozyumu, Tepebaşı Belediyesi, Eskişehir, s 287-295 (In Turkish).
7. Atiş CD, Tartıcı H, Sevim U.K, Özcan F, Akcaözoğlu K, Yüzgeç C., 2002; Afşin-Elbistan uçucu külünün beton katkısı olarak kullanılabilirliği, 5. Uluslararası Inşaat Mühendisliğinde Gelişmeler Kongresi, Eds: Pala&llki, İstanbul, s 161-16(In Turkish).
8. Bentli İ, Uyanık A.O., Demir U, Şahbaz O, Çelik M.S., Seyit Ömer Termik Santrali Uçucu Küllerinin Tuğla Katkı Hammaddesi Olarak Kullanımı, Türkiye 19. Ulu.\tararuxı Madencilik Kongresi ve Fuarı. /MCET2005, İzmir, Türkiye, 09-12 Haziran 2005, 385-392(In Turkish).
9. Sevim, U.K., 2003. Afşin-Elbistan Uçucu Külünün Beton ve Çimento Hamuru ve Harçlarının Üzerinde Yapılan Deneylerle Araştırılması, Doktora Tez Projesi, Proje No: FBE 2002 D 179, 2003(In Turkish).
10. TS 819, Rilem Cembureau Standart Kumu, Ankara, 1976.
11. TS EN 196-3,Çimento Deney Metotları-Bölüm 3: Priz Süresi ve Hacim Genleşme Tayini, TSE, 2002(In Turkish).

ISSN 2056-5860

12. TS EN 196-1, Çimento Deney Metotları- Bölüm-1: Dayanım Tayini, Türk Standartları Enstitüsü, 2002(In Turkish).

13. Akman S., 1990. Yapı Malzemeleri, İTÜ, İnşaat Fakültesi Matbaası, İstanbul, 162s(In Turkish).

14. Erdoğan K, Tokyay M, Türker P., Comparison of intergrinding and separate grinding for the production of natural pozzolan and GYFC in corporated blended cements, Cem. Conc. Res. 29(1999) 743–746(In Turkish).

15. Günlü, A., 1999. Yüksek Fırın cüruflarının Çimento Üretiminde Kullanılmasında Öğütme İle İlgili Parametrelerinin Belirlenmesi, Hacettepe Üniversitesi, Fen Bilimleri Enstitüsü, Maden Mühendisliği Anabilim Dalı, Master Tezi, Ankara(In Turkish).

16. Leimen M.S., Çimento İlle Öğütülen Katkı Maddeleri, Kapasiteleri ve Çevreye Katkıları, Çeviren: Pelin Türker, Çimento Bülteni, 29 (1992) 1-15(In Turkish).

17. Ölmez H.,1988, Endüstriyel ve Tarımsal Atıkların Çimento Üretiminde Değerlendirilmesi, 19 Mayıs Üniversitesi, Araştırma Projesi, No:47, Samsun, 80s (In Turkish).

18. Taşdemir M.A., ÖFYC İnceliğinin Betonun Özelliklerine ve Mikro yapısına Etkisi, Çimento ve Beton Dünyası, 4 (2000) 19–36(In Turkish).

19. Binici H, Aksogan O, Kaplan H, A study on cement mortars incorporating plain Portland cement (PPC), ground granulated blast-furnace slag (GGBFS) and basaltic pumice, Indian Journal of Engineering & Materials Sciences 12 (2005) 214-220.

20. Binici H, Çağatay İ.H, Tokyay M, Kose M.M, The early heat of hydration of blended cements incorporating GGBFS and ground basaltic pumice (GBP), International Journal of Physical Sciences 3 (2006) 112-120.

21. Binici H, Aksogan O, Çağatay İ.H, Tokyay M, Emsen E, The effect of particle size distribution on the properties of blended cements incorporating GGBFS and natural pozzolan (NP), Powder Technology 177 (2007) 140-147.

22. Postacıoğlu, B. 1987.Beton, Teknik Kitaplar Yayınevi,Đstanbul, 175s(In Turkish).

23. Türk Standardları Enstitüsü, 2002, TS EN 196 3: Çimento Deney Metotları- Bölüm 3, Priz Süresi ve Hacim Genleşmesi Tayini. Ankara(In Turkish).

24. Neville A.M., 1988, Properties of concrete. 3rd Edition, Longman & Technical, U.K. 52-54.

25. Temiz H, Binici H, Zülkadiroğlu Ö.F, Termik Santral Külü Katkılı Betonların Yol Kaplaması Yapımında Kullanılabilirliğinin Araştırılması, Fırat Üniversitesi Mühendislik Bilimleri Dergisi 21(2009) 53–61(In Turkish).