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INVESTIGATION OF MECHANICAL PROPERTIES OF CEMENT MIXTURES OBTAINED BY USING MINERAL ADDITIVE MATERIALS

Atila DEMİRÖZ[1,] *, Yasin ÇALI[1]
[1]Konya Teknik Üniversitesi, İnşaat Mühendisliği Bölümü, Konya Türkiye
*ademiroz@ktun.edu.tr, ysncalibey@gmail.com

Abstract

The construction industry has undergone significant changes with the developing technology in the last century. Developments in technology have led to the diversification of materials used in the construction industry. More durable structures have been started to be built against earthquake, liquefaction and different settlements, where soil improvement has been made. Energy consumption in the whole world has increased significantly in recent years due to the increase in the world population and the rapid development of technology. The reduction of natural resources, air and environmental pollution have gained popularity in the idea of using industrial waste materials. Silica Fume (SF), Fly Ash (FA) and Blast Furnace Slag (BFS) are major effective waste materials used in cement or concrete due to their pozzolanic properties. Their usage is very common in our age of improving the soil with additives. With these materials, it is now possible to provide reinforcement, impermeability and structural rigidity. In this study, additive-free Portland cement (CEMI 42,5R) and 0%, 10% and 20% of cement weight SF, 0%, 10% and 20% F type FA, 0%, 20% and 40% BFS and 0%, 1% and 2% Hyper plasticizer (HP) binder material with sand were used and 81 different mortar samples with a water / binder ratio of 0.8 were prepared from their mixtures. After the preparation of samples which were kept for 28 days without changing the humidity, unconfined compressive and splitting tensile (Brazilian) strength tests were carried out on them. The highest unconfined compressive strength (mean 23,52 MPa) was obtained in the sample containing 20% SD, 20% FA and 2% HP in 81 different samples. In the short term (28 days), in samples containing predominantly BFS, the optimum HP ratio was 0%, as the YFC desorbed (shattered) water. However, since SD is fine grained in mixtures containing

SF, the optimum HP ratio was determined as 1%, and this was achieved as 2% since the FA could not fully hydrate in samples containing FA.

Keywords: Blast Furnace Slag, Fly Ash, Hyper Plasticizer, Pand Cement, Silica Fume

MİNERAL KATKI MALZEMELERİ KULLANILARAK ELDE EDİLEN ÇİMENTO KARIŞIMLARIN MEKANİK ÖZELLİKLERİNİN ARAŞTIRILMASI

Özet

İnşaat sektörü son yüzyılda gelişen teknoloji ile birlikte önemli değişiklikler geçirmiştir. Teknolojide yaşanan gelişmeler elbette inşaat sektöründe kullanılan malzemelerin de çeşitlenmesine yol açmıştır. Zemin iyileştirmesinin yapıldığı, depreme, sıvılaşmaya ve farklı oturmalara karşı çok daha dayanıklı yapılar inşa edilmeye başlanmıştır. Dünya nüfusundaki artış ve teknolojinin hızlı gelişmesinden dolayı, dünyadaki enerji tüketimi son yıllarda önemli derecede artmaktadır. Doğal kaynakların azalması, hava ve çevre kirliliği, endüstriyel atık malzemelerin kullanılma fikrine popülerlik kazandırmıştır. Silis Dumanı (SD), Uçucu Kül (UK) ve Yüksek Fırın Cürufu (YFC) puzolanik özelliklerinden dolayı çimento veya betonda kullanılan atık malzemelerin en etkili olanlarıdır. Katkı malzemeleriyle zeminin iyileştirilmesi çağımızda kullanımı oldukça yaygındır. Bu malzemeler ile güçlendirme, sızdırmazlık ve yapısal rijitlik sağlamak mümkün olmaktadır. Bu çalışmada, Katkısız Portland Çimentosu (CEMI 42,5R) ve çimento ağırlığının %0, %10 ve %20'si oranında SD, %0, %10 ve %20'si oranında F tipi UK, %0, %20 ve %40'si oranında öğütülmüş YFC ile %0, %1 ve %2'si oranında Hiper Akışkanlaştırıcı (HA) bağlayıcı malzeme kullanılmış olup, bunların karışımlarından su/bağlayıcı oranı 0.8 olan 81 farklı harç numunesi hazırlanmıştır. Hazırlanan numuneler 28 gün nemi değişmeyecek şekilde bekletildikten sonra üzerinde serbest basınç ve yarmada çekme (brezilyan) dayanım deneyleri yapılmıştır. Oluşturulan 81 farklı numune içerisinde %10 SD, %1 HA içeren numunede en yüksek serbest basınç dayanımı (ort. 24,66 MPa) elde edilmiştir. Kısa vadede (28 gün), baskın oranda YFC içeren numunelerde YFC suyu kusturduğu(cıvıttığı) için optimum HA oranı %0 iken SD içeren karışımlarda SD ince taneli olduğu için optimum HA oranı %1, UK içerenlerde UK tam hidrate olamadığı için bu durum %2 oranında yakalanmıştır.

Anahtar Kelimeler: Yüksek Fırın Cürufu, Uçucu Kül, Hiper Akışkanlaştırıcı, Katkısız Portland Çimentosu, Silis Dumanı

1. Introductıon

Cement-based products, such as mortar, concrete and grout, are the building materials commonly used by human beings in the past and to be used plentifully in the future. It is also one of the most underrated building materials with least known properties and contents. This is because their simple appearance at first glance, their production techniques that is thought to be made by taking directly from nature and therefore to be easy, and the thought it is cheap due to its availability everywhere. Cement is a gray colored powder and concrete is a composite product made of materials such as sand, gravel and cement, but either the chemical structure of the cement or its reactions with water and mineral additives are extremely complex. In case the reactions of cement and mineral additives together are not defined and the results are not determined, it should be taken into account that it may lead to situations that can cause loss of life and property as well as economic loss.

Soil was used in all periods of civilizations both under the construction foundations built for some purposes such as housing and transportation and as a building material. When the structural properties of the soil fail to satisfy in terms of its bearing capacity, it is used as an option for technical solutions such as placing in a deep and solid soil by passing through the soil that does not provide the required bearing service to the foundation, improving the mechanical and physical properties of the poor bearing soil with on-site applications and improving the manmade soils and those suitable for mixing with industrial waste as additives. Problems related to soil encountered in building underground and aboveground structures obliged to use soil improvement methods and directed the studies in this field. In geotechnical engineering field application, the engineering properties of the soil are of great importance for infrastructure and superstructure designs. Bearing capacity of the soil and the layers enabling the permeability are not always at the level to meet the properties desired by the engineer who designs the foundation. “One of the study areas of geotechnical engineering is to bring the negative engineering properties exhibited by the soil to the desired level by using different improvement techniques" [1].

Fly Ash (FA), Silica Fume (SF) and Blast Furnace Slag (BFS) each are known as mineral additives. Hyper Plasticizer (HP) is an artificial chemical additive that is not directly derived from nature. Additives are generally used in the production of injection mortar as a percentage by weight of Portland cement, instead of some amount of cement that is binder, or in addition, sometimes in the form of blended cement by mixing it with cement beforehand.

In thermal power plants, approximately 70 % to 75 % of the ashes that emerge as waste materials by burning pulverized coal try to get out of the chimney with the gases. The very fine-grained powdery particulate material is called as fly ash (FA). FA is kept in the chimneys electrostatically and stored as industrial waste. While the use of FA helps to provide saving from Portland cement, which requires high energy and as a result, has a high production cost, the addition of FA can reduce heat of hydration in fresh concrete, increase workability and injectability, and contribute positively to durability and mechanical strength in set of concrete.

Silica Fume (SF), which is approximately 10 times thinner (15000 m^2/kg) than fine-grained cement, increases the strength and impermeability of concrete by improving the physical and mechanical properties by the means of filling micro voids and aggregate-cement surface in the injection mixture. Due to the silica it contains, it can be able to increase the durability of the concrete by binding calcium hydroxide formed as a result of hydration. To be able to get iron, iron ores are obtained in high temperature furnaces. In these furnaces in which coke is used as fuel, CO and CO2 gases are released with the effect of high temperature and they leave the furnace. Semi-molten iron and mineral additive material called Blast Furnace Slag (BFS) remain. BFS reduces the hydration heat in concrete and porosity in mortar, and also increases its chemical resistance.

Chemical plasticizer additives are generally examined in three parts which are normal, super and new generation Hyper Plasticizers (HP). It is one of the indispensable components of the building sector because of the improvements it provided in the mechanical properties of mortar and concrete. Chemical additives play an active role in the limitations of the mixing and placing times of concrete and in the problems during placement. Chemical additives react physically and physico-chemically and change the properties of the binders by interacting with cement and, they change the properties of the mortar by interacting with water. Generally speaking, additives defined as agents that change the properties of mortar and concrete in fresh or hardened state are used extensively in Turkey in recent years. Thanks to these additives, it cane be obained normal workability at very low water/cement ratios. Workability loss of hyperplasticizers (HP) developed in recent years can be eliminated, and the soilcrete can immediately get to high strength a day later [2].

SF and FA contribute to concrete strength and chemical reactions in concrete as much as their quantity. When it is not used measuredly, it can decrease the workability by increasing the water requirement in the reaction. It can reduce the ultimate compressive strength within 3 to 7 days. It is expected from fly ash to reduce shrinkage and from silica fume to increase shrinkage [3]. When examining the cost of SF for such reasons, it causes SF not to be used widely when compared to other binders (BFS and FA etc.). Unmeasured use of the BFS causes to vomit the water in the mortar and causes it not to set, like in the plasticizer. In this study, the use of additives such as industrial waste, SF, FA and BFS together in the quantitiy sufficient to make was investigated in many mechanical properties such as strength, permeability, workability, shrinkage. When performing a literature research, according to the results of unconfined compressive strength, tensile splitting strengt, it is concluded that it can be used as additive in single mixes at the level of 5-25% FA, at the level of 5-25% SF and at the level of 10-50% BFS and in the mixes containing two additives at the level of 5-10% SF, at the level of 10-15% FA and at the level of 10-15 % SF together with 5-20% BFS and in the mixes containing more than two additives at the level of 5-10% SF, together with 5-10 FA and BFS. In general terms, it is recommended that the ratio of additives should not exceed 40% by weight [4]. In this study, the relationship between the unconfined compression and tensile splitting strength of the mortar samples obtained by using additives, the type and quantity of the additive and the mixing parameters of the binders with each other are investigated.

2. Materials and Methods

Soil used in the experimental laboratory study was a round grained sand soil and was obtained from the sand quarry in Eğribayat District of Konya City. In order to determine the mechanical properties of the sand brought to the laboratory, sieve analysis was performed and granulometer criteria of the sandy soil were determined. Soil class was determined according to TS1500/2000 and ASTM standards (Table 2.1).

In the study, the sand brought from Eğribayat sand quarry located in Selçuklu County of Konya City was washed and soil mechanics tests were carried out. Physical properties were determined by sieve analysis and specific bulk density tests on sandy soil (ASTM D 6913-04, 2009, ASTM D 854-10, 2010), and soil class was determined according to TS1500-2000 (TS1500, 2000).

Grain size distribution (Granulometry) curve of sand: It was found the grain diameter distribution as a result of sieve analysis performed in accordance with ASTM standards in the laboratory for the testing sand. According to the USCS soil class, it falls into the soil class of well-graded sand (SW). Sieve analysis test results are given in Table 2.1. In the soil, there are 77.74% coarse sand and 18.08% fine sand with 0.12% fine grains. The grain size distribution curve is given in Figure 2.1.

Table 2.1. Physical properties of sand

Soil Class	SW
Effective Grain Size D_{10} (mm)	0,17
D_{30} (mm)	0,70
D_{60} (mm)	2
Coefficient of Uniformity, C_u	11,77
Coefficient of Gradation, C_c	1,44

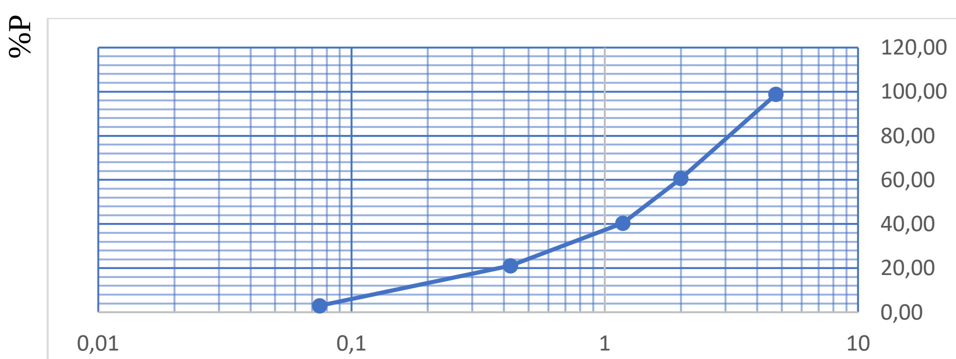

Figure 2.1. Granulometry curve of sand used in the test

Grain bulk density of sand: In order to determine the grain bulk density of the testing sand, pycnometer tests were performed in the laboratory. According to the results of the pycnometer test performed, average grain bulk density was found to be γ_s= 26,39 kN/m$^{3.}$

Maximum and minimum dry bulk density of sand: In order to determine the maximum and minimum dry bulk density (void ratios) of the sand used in the tests, it was performed tests with proctor moulds in accordance with the standards. Table 2.2 gives the maximum and minimum void ratios of the sand corresponding to the dry bulk density determined by the test (ASTM D 4254, 2006, ASTM D 4253, 2002) (Figure 2.2).

Figure 2.2. Sieve and pycnometer analysis

It was determined the maximum and minimum void ratios of the sand to be used in samples with additive mixtures. Tests were performedt according to the conditions specified in ASTM D4253 (Standart Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table) and ASTM D4254 (Standart Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density). In the calculation of maximum and minimum void ratios, it was used a mould that has a diameter of 10.4 cm, a height of 11.1 cm, a weight of 4284.5 g and a volume of 942.5 cm^3. Standard compaction tests were performed according to (ASTM D 4254, 2006) and (ASTM D4253, 2002) standards in order to determine the minimum void ratio (e_{min}). In Table 2.2, the maximum and minimum void ratios of the sand corresponding to the dry bulk density determined by the test are given.

Table 2.2 Results of dry bulk density and void ratio tests

Specific Bulk Density, γ_s (kN/m^3)	26,90
Dry bulk density in loose state, $\gamma_{k,\ min}$ (kN/m^3)	14,20
Dry bulk density in rammed state, $\gamma_{k,\ max}$ (kN/m^3)	19,50
Minimum void ratio (e_{min}), (%)	37,80
Maximum void ratio (e_{max}), (%)	89,40
Degree of Compactness, (D_r), (%)	35,00
Void Ratio (e), (%)	71,60

2.1 Normal Portland Cement (CEM I - 42,5R)

Cement is the hydraulic binder materials produced by grinding the clinker, which is the semi-finished material obtained by cooking raw materials containing Si, Ca, Al, Fe (limestone and clay mix) up to sintering degrees (1250-1450 ^oC) by adding single or more additives (gypsum, trass, limestone, slag). The main raw materials of Portland cement clinker are limestone and clay. These two substances are not found in pure state in nature. There are several foreign substances in them and they are included in cement. Therefore, besides its main components such as CaO, SiO_2, Al_2O_3 and Fe_2O_3, which constitute 90% of Portland cements, it is also includedMgO, SO_3 and Alkali oxides. In this study, CEMI 42,5R additive -free Portland cement produced by Company Konya Çimento A.S was used in preliminary tests and Jet Grout injection. Chemical analyzes were performed in Company Konya Çimento Sanayi ve Ticaret A.S. and Pycnometer analysiswere performed in Geotechnical Laboratory, Konya Technical University. Results are given in Table 2.3.

Table 2.3. Chemical content and physical properties of cement

Component (%)	PKÇ CEMI 42,5R
SiO_2	20.83
Al_2O_3	5.14
Fe_2O_3	3.01
CaO	63.87
MgO	2.47
SO_3	2.50
Na_2O	0.15
Pecific Bulk Density (kN/m^3)	31,0
Surface fineness (cm^2/g)	3740

2.2. Silicafume (Micro Silica)

Pycnometer analysis of SF brought from Antalya Plants of Eti Elektrometalürji A.Ş was performed in Geotechnical Laboratory, Konya Technical University. Chemical analysis and results are given in Table 2.4.

Table 2.4. Chemical content and physical properties of Silica Fume

Component (%)	Silica Fume
SiO_2	94,94
Al_2O_3	0,7
Fe_2O_3	0,6
CaO	0,83
MgO	0,71
Specific Bulk Density (kN/m^3)	28,50
Surface Fineness (cm^2/g)	130 000- 200 000

Very fine and rounded silica fume grains enter into the larger cement grains, push the squezeed water out and activates it on the consistency of the fresh paste. Despite this positive effect, the large surface area formed by silica fume grains will increase water requirement and affect the consistency negatively. Therefore, the result may change depending on factors such as cement and silica fumes in the paste and ratio of water/binder material (b / w). According to the studies, silica fume, which is added up to 5% of the cement, does not change the water requirement too much, and in larger quantities, the water requirement increases. It associates the positive effect of Silica fume additive on concrete strength, rather to strengthening the aggregate-paste interface. According to some people, considering an average of every cement grain, two million of silica fume grains enter, when it is added instead of 15% of the cement. Fine silica fume grains fill the gaps in the interface, less water is collected under the aggregate grains, because the bleeding decreases, and the physical adherence between the paste that becomes more adhesive and the aggregate grains increases

Because of its superfine grains and high amorphous silica content, silica fumes react with CH in cement paste (with calcium hydroxide ($Ca(OH)_2$), the reaction product of cement with water)) and forms the pozzolanic C-S-H gel. C-S-H Gel ensures strength in concrete and it is the product that is desired to be formed. $Ca(OH)_2$ is the phase which does not contribute to strength, which is water-soluble and is responsible for the hollow structure of concrete. It is preferred to have a minimum quantity in concrete. According to the researchers, the pozzolanic gel in the paste with silica fume additive is included within the voids of C-S-H gel that forms normally and as a result, a very dense gel structure emerges [5] Equation (1-2)

$$\text{Cement} + \text{Water} \longrightarrow Ca(OH)_2 \tag{1}$$

$$\text{Reaction of Silica Fume} \longrightarrow SiO_2 + \text{Water} + Ca(OH)_2 \longrightarrow \text{C-S-H Gel} \tag{2}$$

Silica fume reacts earlier and faster than Ca (OH) 2, which is the reaction product of water with cement, compared to other pozzolanic materials such as fly ash and blast furnace slag. There is a physical effect of silica fume on the reaction of cement with water as well as its chemical effect. Due to the fineness and mineral structure of silica fume, this accelerates the reaction of cement with water and expedites the process of gaining strength. It is recommended to add water reducer super or hyper plasticizer to mixtures, since it reduces water content to mixtures where silica fumes are substituted. Because the consistency of silica fume materials containing the same quantity of water will be more intense, it is recommended to prepare concretes prepared with silica fume replacement at a high initial slump value up to 50 mm. If the curing conditions are the same, the silica fume replacement increases the compressive strength of the concrete at all ages with the only difference in the mixture design is silica fume. The two greatest reasons for using SF as as additive in concrete are its developments in permeability and strength. Increase of SF mixtures in compressive strength depends on the water/cement ratio that is very low than the quantity of SF in cement. Compressive strength increases up to the addition of 20% SF and achieved the level of 10 to 15 % maximum strength. However, strength gaining power is 15% less than reference concrete [6].

Relationship of silica fume with other mineral additives such as fly ash and blast furnace slag has been investigated. Silica fume can be useful in increasing low early strengths caused by other pozzuolanas. CH, initially formed during cement hydration, is bound by silica fume, and other pozzuolanas and react with the remaining CH. When appropriate ratios are used in this way, strengths with silica fume and mineral additives at both early and later ages can be positively affected. Extended setting times in pastes with fly ash additives can be shortened when 8% silica fume is added. Silica fume is often used together with superplasticizing additives. Polymer molecule chains contained in these additives are absorbed on the surface of the cement grains. This allows cement grains to be easily dispersed in the paste by pushing each other and reduces the mixing water required for the same consistency. In case there are silica fume grains in the environment, the main characteristics of this effect do not change [7]. There should be 55-60% C3S in an average clinker. Silica fume additive especially accelerates calcium silicate (C3S) hydration. It can be said that silica fume will be more effective in cements with high quantity of C3S, since it will bind CH formed by this reaction and convert it to C-S-H gel.

2.3. Fly Ash (FA)

Molten material, which emerges as a result of the burning of coal at high temperatures, cools and turns partly or wholly into spherical shaped ash grains with the gas flow. The main components found in fly ash are in the ratio of SiO_2 (25-60%), Al_2O_3 (10-30%), Fe_2O_3 (1-15%) and CaO (1-40%), and values in these different ranges characterize the fly ash type.

Fly ashes, which are produced from bituminous coal and whose total percentage of $SiO_2+Al_2O_3+Fe_2O_3$ is more than 70%, are classified as class F fly ash. Since the percentage of CaO in these ashes is also below 10%, they are also called low-lime Class F fly ashes have pozzolanic nature. Class F fly ash used in the study was obtained from Seyitömer Thermal Power Plant. According to the TS EN 197-1 standard, it is also classified as class F (siliceous fly ash) because the quantity of reactive lime is below 10% and the quantity of reactive silica is above 25% [13].

According to the standard of ASTM C 618 and $SiO_2+Al_2O_3+Fe_2O_3>70\%$ ve CaO <10%, fly ashes of Seyitömer are classified as class F (low lime ash) [12]. Pycnometer analysis of class F FA brought from Seyitömer Thermal Power Plant, ARES ÇİMENTO A.Ş. was carried out in Geotechnical Laboratory of Konya Technical University. Chemical analysis and results are given in Table 2.5.

Table 2.5. Chemical content and physical properties of FA

Component (%)	Class F Fly Ash
SiO_2	54,49
Al_2O_3	20,58
Fe_2O_3	9,27
CaO	4,26
MgO	4,48
MnO	1,75
SO_3	0,52
Reactive lime	2,49
Reactive Silica	39,01
Specific Bulk Density (kN/m^3)	21,20
Surface Fineness (cm^2/g)	3300

Fly ash positively affects many properties of concrete and improves its resistance to chemical effects, if used properly and in proper proportions. In recent studies, different approaches were used to accelerate the pozzolanic reaction of fly ash, and with these approaches, fly ash was activated and paved the way for its use as an important additive in building materials [8]. They stated that replacement of every 10% of cement in the concrete mix with FA reduced water requirementby 3-4%.

Thus, they emphasize that the void ratio decreased significantly. While FA added to cement by 40% extend the setting time, shortening of the setting time can be achieved by 25-30 minutes by adding SF instead of ash by 8% [9]. Mixtures containing FA and prepared at low water/binder ratios exhibit better resistance than mixtures prepared at high water/binder ratios. Also, the contribution of fly ash to strength is better in concrete mixes than in mortar mixtures [10].

They say that concrete with FA has relatively weak characteristics at early ages, but concrete with SA has achieved the strength and bearing characteristics in the long term [8]. The effects of using FA as an additive on concrete strength is similar to the fine-grained natural pozzolan effect. Normally, in the early stages, the strength of concrete with FA is slightly less compared to additive-free concrete. However, final strength is quite high. Increase in strength in the first days varies according to the fineness and type of the FA [11].

2.4. Blast Furnace Slag (BFS)

Slags are one of the waste material groups obtained from various metallurgical plants. Depending on the main product type and production method produced by the industrial enterprise they obtained, their chemical compositions and properties differ greatly from each other. Although blast furnace slags have their own binding properties, nickel and copper slags only have pozzolanic properties.

Slags have a wide range of opportunities to use in the cement and concrete industries. Slag with a vitreous structure and some hydraulic properties are obtained in the facilities where steel is manufactured with a modern technology. It is possible to use them in cement systems and injections. Among all slags, the most important and most widely used is the blast furnace slags (BFS). BFS, containing a large amount of silica and alumina, exhibits similar properties to the pozzolanic properties of natural pozzuolanas and fly ash if milled to a very fine grain.

Also, because it contains a large quantity of CaO, the milled BFS would have some binding properties by itself. Milled BFS can have area of use just like fine grained natural pozzuolanes or FAs. In other words, it can be used as a hydraulic binder by combining calcium hydroxide in an aqueous medium, and can be employed in the production of slag cement and as a concrete additive by grinding together with Portland Cement clinker and a small amount of gypsum [3].

Reaction of BFSs with water alone develops rather slowly compared to the hydration of Portland Cements. Hydration of the slag can be defined as the partial dissolution of the slag in water, precipitation of C-S-H, hydrated aluminates and hydrated silico aluminates [12]. Slowly progress of BFS's reaction with water alone caused many researchers to work on activators that will accelerate this reaction. As a result of studies performed approximately since 60 years, it is possible to collect the materials used for the chemical activation of slags in two main groups: Alkaline activators (soda, lime, sodium, carbonate, sodium silicate, etc.) and Sulfate activators (gypsum, anhydride, phospho-gypsum, etc.). Chemical analysis of BFS brought from Adana Çimento A.Ş.'s İskenderun Facilities was carried out in Oysa Çimento Sanayi ve Ticaret A.Ş, and the Pycnometer analysis was performed in the Geotechnical Laboratory of Konya Technical University. The results are given in Table 2.6.

BFS increases workability in added mixtures. It extends the setting time of the mortar, reduces bleeding and hydration heat in the colon formed. It reduces the water permeability of the set mixture. It als increases the sulfate resistance of hardened concrete. It contributes to the workability in the mixture and desorbs the grouting, even if just a bit, and water downs the concrete. Partial precipitation occurs in the samples made in preliminary tests. Especially in cold weather, as it causes late setting, the resistance increase in the early days develops more slowly.

Table 2.6. Chemical content and physical properties of BFS

Component (%)	Blast Furnace Slag
SiO_2	35,0
Al_2O_3	16,0
Fe_2O_3	1,40
CaO	37,50
MgO	5,25
MnO	1,75
Specific Bulk Density (kN/m^3)	28,50
Surface Fineness (cm^2/g)	4750

2.5. Hyper Plasticizer (HP)

It is a chemical additive that provides reduction of the high quantity of water without changing the consistency on the concrete or that increases the precipitation without changing the quantity of water, or that creates both effects together. Plasticizers are generally used in practice for three purposes;

- Ensuring higher strength by reducing the water/cement ratio, provided that it has the same workability with additive-free concrete.
- Obtaining the same workability, in case of reducing the quantity of cement in order to reduce the hydration heat in mass concrete. Use of additive in this way also means that it provides a more economical concrete production.
- Increasing workability to ensure easy placement in inaccessible places

Chemical and physical properties of plasticizer additive branded CHRYSO * DELTA 1115-3 from company SANCAK HAZIR BETON A. S's concrete plant are given in Table 2.7 Product complies with TSE EN-934-2 standard.

Table 2.7. Chemical and physical properties of Hyper Plasticizer

Result	Hyper Plasticizer
Color and Appearance	Brown and Homogeneous
Density (gr/cm^3) (20^{o}C)	1,151
pH	6,32

3. Results and Discussion and Conclusion

3.1. Performing Tests

In this study, the strength effect was invstigated by preparing preliminary samples with cement and additive mixture in the sizes of 50 x100 mm in the Geotechnical Laboratory, Department of Civil Engineering, Faculty of Engineering and Natural Sciences, Konya Technical University. Sample preparation steps in the experimental study is seen in Figure 3.1.

Diameter of the PVC pipe used in the experimental study is 50 mm and its height are 100 mm. Levels and proportions of the mortar samples formed are given in Table 3.1. One of the parameters affecting the strength of mortar is the water/binder ratio of the injection material. Water/binder ratio (s/b= 0.8) used for the preparation of the injection material was remained the same for the purpose of comparison. Thus, it is aimed to have information about the ratio and effect of additives.

First of all, a sieve analysis is performed on the sand not containing organic matter from the sand quarry. For the appropriate mixture, sand is kept in the drying oven at 100 ± 5 degrees for 1 day and the water content in the sand is reduced to zero. Sand coming out of the drying oven is left to rest. It is weighed in 2 duplications and its weight will be increased since it will be mixed up in the mixing bowl. Sand is mixed in a bag with additives in the intended proportions. After the sand is mixed homogeneously with the additive, it is transferred to a container for adding and mixing the intended quantity of water. It is transferred to the PVC containers after being mixed in the container in the time specified in the specification. After obtaining the intended setting (2-3 days), the samples are removed from the moulds by means of a sample remover through a simple piston machine. Samples are left in a damp-dry bag in order not to lose moisture. It is applied the curing period specified in the specifications (28 days). 50 mm width of pipes are cut along 100 mm and the mould length is adjusted as to be twice the diameter. In order to remove the samples easily and make additives not to adhere to the internal wall, the PVC inner surface is lubricated with grease. Bottom of the container is covered with a leak-proof bag. Containers are pre-labeled in order to avoid mixing samples

Figure 3.1. Formation of samples created by using additives

3.2. Fracture of Samples

Uniaxial compression test is performed in order to measure uniaxial (Free) compression of fine-grained soils. Test can be performed on saturated, unsaturated clays, sands and cemented soils. At the same time, deformation-load change is determined. Cylindrical soil sample is subjected to loading only in axial direction.

Length shortening of the sample emerging under axial load increases is measured and stress-strain curves are obtained. The greatest value of normal stress (or its value corresponding to the deformation in a level accepted as slump) gives the unconfined compressive strength value of the soil. In order not to intersect with the upper and lower loading heads of slip planes, it is appropriate to select the length/diameter ratio. Unconfined compressive test can only be applied on the soil that can be able to hold itself straight without any lateral support.

And in the application of the test in the Brazilian test, the sample is laid on the test press in such a manner that the axis of the sample is parallel to the bottom plate of the press. Plywood slats in 25 mm width and about 3 mm thickness are placed on the lower and upper parts of the lateral facade of the sample. Compressive load applied by the test press is maintained until the sample is fractured and then, fracture load (P) is measured. Under such a loading, the fracture style of the cylinder sample occurs in the form of splitting the sample into two parts (Figure 3.2).

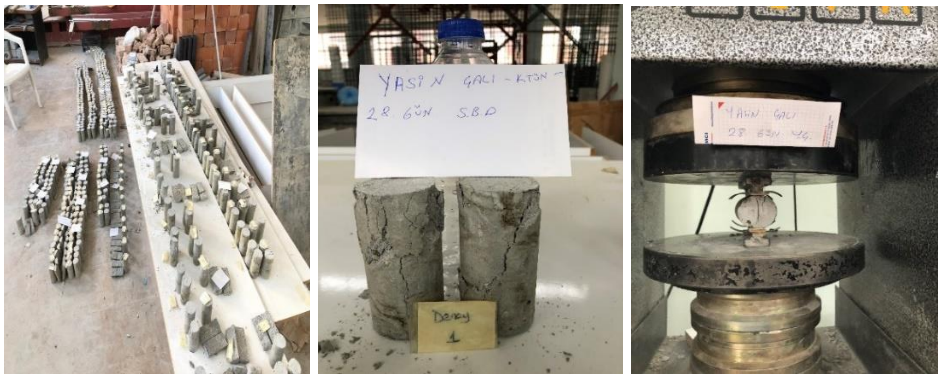

Figure 3.2. Examination of compressive strength of the samples formed

When examining unconfined compression and tensile strength of the samples formed in this study, it was seen that it increased the strength and ductility of the additives in accordance with the literature studies. Samples are also cut in accordance with the specification that will have height/diameter ratio which is 2, and after the upper and lower surfaces are corrected, unconfined compressive and tensile splitting strength tests are carried out on the samples. Samples were fractured at a loading speed of 0.4 mm/min. Test results of the fractured core samples are given in Table 3.1.

3.3. Evaluation of Test Results

In the study, it was seen that the samples formed by using Silica Fume (SF) and Fly Ash (FA) were found to be higher in terms of unconfined compressive test and splitting tensile strength than the additive-free normal Portland cement sample and lower than those containing Blast Furnace Slag (BFS). Because these values may vary for longer periods and broader scopes, they need to be investigated.

Since the fineness of SF is much more than the specific surface area of normal Portland cement (NPC), the lengths and strength values of the samples formed by using SD were higher. C-H and ettringite structures in many C-S-H gels improve strength.

In samples containing BFS, precipitates were seen as in HPs and its delayed setting. Samples containing BFS and HP were observed to set in approximately 48 hours. This is because the BFS has a larger size of grain compared to FA and SF and does not provide the fullt intended puzzolanic behavior bcause of the SiO_2 ratio it contains.

Table 3.1. 28-days strength results of samples

Test No	BFS	SF	FA	HP	Mean.Mpa UCT	Mean.MPa STS	Test No	BFS	SF	FA	HP	Mean.Mpa UCT	Mean.Mpa STS
1	0	0	0	0	14,98	2,64	**43**	20	10	20	0	16,36	2,94
2	0	0	0	1	15,34	2,47	**44**	20	10	20	1	12,00	3,11
3	0	0	0	2	10,38	2,47	**45**	20	10	20	2	20,21	2,45
4	0	0	10	0	16,21	3,06	**46**	20	20	0	0	16,48	3,01
5	0	0	10	1	16,12	3,14	**47**	20	20	0	1	24,06	3,53
6	0	0	10	2	18,53	2,83	**48**	20	20	0	2	23,25	3,15
7	0	0	20	0	16,24	2,83	**49**	20	20	10	0	17,32	2,71
8	0	0	20	1	17,17	2,82	**50**	20	20	10	1	22,44	3,49
9	0	0	20	2	18,28	2,45	**51**	20	20	10	2	21,41	3,32
10	0	10	0	0	21,44	3,00	**52**	20	20	20	0	13,02	2,74
11	0	10	0	1	23,40	2,68	**53**	20	20	20	1	17,68	3,03
12	0	10	0	2	16,99	3,52	**54**	20	20	20	2	18,98	2,70
13	0	10	10	0	18,83	3,41	**55**	40	0	0	0	12,60	2,59
14	0	10	10	1	21,74	3,82	**56**	40	0	0	1	12,57	2,50
15	0	10	10	2	16,99	3,16	**57**	40	0	0	2	13,23	2,29
16	0	10	20	0	14,26	2,44	**58**	40	0	10	0	15,04	2,34
17	0	10	20	1	17,74	3,44	**59**	40	0	10	1	14,74	2,25
18	0	10	20	2	20,12	2,97	**60**	40	0	10	2	14,13	2,19
19	0	20	0	0	18,04	3,14	**61**	40	0	20	0	11,73	2,17
20	0	20	0	1	23,10	3,59	**62**	40	0	20	1	12,24	2,13
21	0	20	0	2	19,40	4,06	**63**	40	0	20	2	12,00	2,10
22	0	20	10	0	17,35	3,30	**64**	40	10	0	0	15,64	2,56
23	0	20	10	1	22,22	3,20	**65**	40	10	0	1	19,52	2,52
24	0	20	10	2	19,37	3,89	**66**	40	10	0	2	20,99	2,63
25	0	20	20	0	16,54	2,28	**67**	40	10	10	0	12,90	2,56
26	0	20	20	1	19,88	3,76	**68**	40	10	10	1	15,04	2,36
27	0	20	20	2	23,52	3,46	**69**	40	10	10	2	15,22	2,96
28	20	0	0	0	14,74	2,23	**70**	40	10	20	0	10,86	1,68
29	20	0	0	1	14,59	2,43	**71**	40	10	20	1	12,03	2,29
30	20	0	0	2	13,86	2,45	**72**	40	10	20	2	13,08	2,29
31	20	0	10	0	16,09	2,91	**73**	40	20	0	0	15,52	2,61
32	20	0	10	1	14,77	2,60	**74**	40	20	0	1	16,66	2,82
33	20	0	10	2	14,44	2,48	**75**	40	20	0	2	15,64	2,77
34	20	0	20	0	14,38	1,94	**76**	40	20	10	0	10,59	2,00
35	20	0	20	1	15,46	2,10	**77**	40	20	10	1	13,47	2,44
36	20	0	20	2	15,25	2,50	**78**	40	20	10	2	14,56	2,61
37	20	10	0	0	17,83	3,46	**79**	40	20	20	0	7,70	1,53
38	20	10	0	1	15,88	2,73	**80**	40	20	20	1	9,08	1,72
39	20	10	0	2	16,12	3,18	**81**	40	20	20	2	11,04	1,85
40	20	10	10	0	15,58	3,31							
41	20	10	10	1	18,92	3,05							
42	20	10	10	2	16,06	3,06							

However, the compressive strength of BFS with 20% additive by weight in 28 days reached to 98% of additive-free PC and the compressive strength of BFS with 40% additive by weight in 28 days reached to 84 % of additive-free PC.

Since the solid grains suspended in the mixture cannot come together due to their electrical charges in water, this can be explained by the fact that the coagulation (precipitation) is good for disrupting this electrical environment and bringing the particles into masses that can precipitate in water. Therefore, it is considered that it will be useful to use modern techniques in which we can monitor structural changes such as XRD, SEM as well as standard cement tests.

It was observed that, in the samples with BFS compared to NPC samples, early strength decreased with the reduction of the quantity of CH that releases with BFS additive. It was reported by the literature researches that BFS with pozzolanic properties will bind the remaining CH in later ages, turn it into a new (pozzolanic) C-S-H gel, block the pores and lower the hydration temperature. Therefore, it is thought that sulfate resistance will be ensured depending on the time and the strength and durability will increase

In the samples with additives, generally, more ductile behavior was observed compared to additive-free NPC. When HP was not added, it was observed stress in the formation of mortar. Mixtures containing 1% HP showed even greater ductility than other mixtures. This is becauset it causes an increase in binding due to the contribution of HP to the change of water/binder ratio.

Since it is considered that mixtures containing 2% HP significantly reduce water requirement, they increase the void ratio in the sample and accordingly weaken its mechanical properties.

It was observed that the pressure values were maximum in 0% phase of HP in YFC included in the mortar predominantly, in 1% phase of HP in SF included in the mortar predominantly, and in 2% phase of HP in FA included in the mortar predominantly. The reason is considered as that since blast furnace slag dilutes the mortar (watering down), it desorbs the water in the mortar and increases the water/binder ratio, that silica fume is saturated with water at HP value after 1%, that the void ratio is increased and that the fly ash reaches more pozzolanic reaction together with higher water requirement and water increase

It was seen that maximum values are obtained in mixtures no: 11, 20, 23, 27, 47, 48 and 50. Here, it was observed that SF increased strength in the short term because of its contribution to the setting in the early period.

In case of use of FA, it should not be used below a certain water/binder ratio. It is recommended not to use BFS too much with HP.

When the ratio of additives exceeds 50%, it cannot act as cement, which is the binding agent. This is because cement with additives cannot form C-S-H bonds. C-S-H bond is formed by CaO in cement and SiO_2 additives and H_2 from water.

Cement contains some SiO_2 in it. Excessive quantities of $SiO_2$and other additives do not affect only strength, but also cause low strength. In summary, the additives are the auxiliary elements, but the main raw material is cement.

Since the samples are hand prepared and small-scale, it was approved and found useful to examine their long-term (56 days) strengths with jet grout and similar tests in the field and laboratory for the validation of accuracy of the results.

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