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Investigating of Mechanical Properties of Mortars Based on Fly Ash and Blast Furnace Slag Activated with Alkali

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***Abstract*— *Alkali activated mortars obtained from granulated blast furnace slag and fly ash were used instead of Portland cement by activating with alkali. Sodium silicate and sodium hydroxide were activated blast furnace slag and fly ash. Mortar samples were prepared 40x40x160 mm as prismatic samples according to TS EN 196-1 and they were cured at room temperature. Compressive and flexural strength of the mortar samples including blast furnace slag and fly ash were investigated by experimenting.*
Keywords*— *Alkali activation, blast furnace slag, compressive strength, flexural strength.

I. INTRODUCTION

Portland cement is an excellent hydraulic binder and Portland cement based products are the most commonly used building materials in the world. However, due to the fact that cement is produced in huge volumes all over the world, cement production also brings problems related to economy, energy and environment. Global warming publications report that the cement industry accounts for 10% of the total CO_2 emissions on Earth. One of the ways to solve problems related to economy, energy and environment in connection with cement production is to develop alternative binding materials with cement-like properties. For this purpose, mortars are produced by using blast furnace slag and fly ash instead of cement.

Alkali-activated mortars are obtained by using blast furnace slag and fly ash binder instead of Portland cement as binders and activating with alkalis. Alkali-activated mortars, when compared to normal Portland cement mortars, reported that they had higher durability in low hydration heat, high early strength and aggressive environmental conditions. The strength and workability of alkaline activated mortars vary according to the alkali type.

1.1. Blast Furnace Slag

Blast furnace slag is a pozzolanic material, which is not a sole binding property containing high amounts of SiO_2 and Al_2O_3 but which has binding properties when used with another binder such as cement and which is obtained during iron production. The blast furnace slag, which is very hot in its production, should be rapidly cooled to a granule and high-grade material so that it can exhibit better pozzolanic properties. Blast furnace slag is used instead of cement used as binder in concrete production. A lot of studies have been done on the use of this mineral binder, which is an industrial by-product. Tokyay and Erdogdu (2003) showed that reducing the impermeability of concrete is one of the most important factors in increasing concrete durability [1].

Peter and Jack (1996) stated that the blast furnace slag should be grinded to a fineness of at least 400 m2 / kg, which is finer than Portland cement, as the hydraulic binding of granulated blast furnace slags will be better with finer grinding [2]. Wang et al. (1994) pointed out that the reaction of granular blast furnace slag with water is rather slow, when compared to the hydration of Portland cements, so that these reactions are accelerated to accelerate this hydration rate [3].

Alkali-activated slag cement and concrete have been found in Ukraine for the first time in 1957, although their work on alkaline activation of slags dates back to 1940s. The slag alkaline activation has been studied extensively since the 1970s, and in recent years alkali-activated slag cement and slag substituted concrete have begun to attract a great deal of attention, including the work done [4]. Bilim and Atiş (2012) used 3 different liquid sodium silicate doses for activation in a study carried out by substituting cement for 0, 20, 40, 60, 80 and 100% by weight in order to study the effect of alkali activated slags. It was determined that the compressive and flexural strength of the produced specimens increased with the increase of the slag ratio and the activator concentration used [5]. Altan and Erdoğan (2012) investigated the effects of different alkali activation parameter influences and how they affected the improving strength of slag mortar at room temperature and at high temperatures [6].

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1.2 Fly Ash

Fly ash is a pozzolanic material obtained with the help of electrostatic filters or filter bags to keep particles moving together with flue gases during the burning of high calorific coal in hydroelectric power plants. Erdoğan (1997) observed that more than 99% of this material could be retained. They are not binding on their own and gain binding properties when used with other binding materials. Fly ashes are classified according to their SiO2 and Al2O3 components. Fly ashes are used instead of cement in concrete [7]. Tonak et al. (1989) emphasized that the economical feature of fly ash, which is cheaper than cement. Since the 1930s, the use of fly ash has become widespread with the development of the electric energy generating company using coal raw materials. Studies of fly ashes first appeared in North America in 1937 [8]. Gökçe (1995) study, the rapid increase in energy costs indicated that the significant increase in cement prices in the 1970s has created an environment in which fly ash begins to be used all over the world [9].

Fly ash produced in one year in the world is evaluated in less than 25% of different areas. However, more than 95% of total fly ash produced in Germany, Holland and Belgium is used, and about 50% in England. Bhattachariee and Kandpall (2002) point out in their studies that large quantities of fly ash are produced in the US and China, and about 32% and 40% respectively of the produced pheasant [10]. Tokyay (1993) stated that the use of fly ash in Turkey is less than 1% when the 1990 data are taken into consideration [11]. Fernández and Palomo (2005), it was found that the sample pressure resistance changed between 35-40 MPa as a result of activation with fly ash sodium hydroxide and curing at 85 ° C for 24 hours. In addition, it has been found that the pressure resistance can be increased up to 90 MPa if sodium silicate is added to the mixture [12]. Lee and Lee (2013) investigate the effects of cement mortars made with fly ash on flexural and compressive strength, settling time and void ratio [13].

II. MATERIALS AND METHOD

In the study, blast furnace slag and fly ash were used instead of cement in various proportions. Sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_4) were used to activate blast furnace slag and fly ash. The physical and chemical analysis results of the cement used in the study are given in TABLE 1, in TABLE 2 and TABLE 3.

Blast furnace slag and fly ash with chemical properties were used in place of cement in suitable proportions for 4 different tests. As aggregate, standard sand according to TSE EN 196-1 was used [14]. Lab-bed 779 plasticizing admixture was also used in some experiments. The samples were stored for 28 days under the curing conditions specified by the standard. Upon reaching their 28 day strengths and other physical properties according to CEM I 42.5 R were examined. Mixing ratio of mortar mixture: water: binding materials: sand ratio, 1: 0.5: 3 as the mixture prepared, 40x40x160 mm size molds are poured. The 28-day properties were examined. 4%, 6% and 8% Na + concentrations were determined as the activator doses to be used in the activation according to the amount of binder. The water / binder ratio in the mixtures was kept constant at 0.50. In order to keep the water / binder ratio constant, taking into account the amount of water in the solution, the amount of water to be added to the mortar mixtures is also adjusted by decreasing. The 40x40x160 mm prismatic mortar samples obtained from the prepared mixtures were kept at room temperature until the test days.

Table.1: Chemical and physical analysis of cement.

Chemical composition	CEM I 42,5 R
CaO (%)	66,04
SiO_2 (%)	13,01
Al_2O_3 (%)	3,47
P_2O_5 (%)	7,6
MgO (%)	1,23
Na_2O (%)	0,27
K_2O (%)	0,93
SO_3 (%)	4,6
Specific gravity	3,18
Blaine fineness (cm^2/g)	3352
Loss of ignition (%)	1,98

Table.2: Chemical analysis of fly ash.

Chemical composition	Fly Ash
SiO_2 (%)	45,170
Al_2O_3 (%)	11,161
Fe_2O_3 (%)	7,403
CaO (%)	14,050
MgO (%)	4,696
Na_2O (%)	2,074
P_2O_5 (%)	8,286
K_2O (%)	4,163
SO_3 (%)	2,616

Table.3: Chemical analysis of blast furnace slag.

Chemical composition	Blast Furnace Slag
SiO_2 (%)	34,09
Al_2O_3 (%)	12,19
Fe_2O_3 (%)	0,61
CaO (%)	30,82
MgO (%)	6,14
Na_2O (%)	0,56
P_2O_5 (%)	0,03
K_2O (%)	0,45
SO_3 (%)	1,57

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III. RESULTS AND DISCUSSION

In this chapter, quantities of materials used in the research that was carried out with Blast furnace slag and fly ash mortar mixtures activated with Alkalis are presented in TABLE 4.

As seen in TABLE 4 blast furnace slag and fly ash have been activated at different ratios. The ratios of mortar mixtures were selected in accordance with TS EN 196-1 [14]. In these studies, mixtures were prepared in such a way that the ratios of the binder, water and standard sand confirming TS EN 196-1 used in the mortar were respectively 1:0.5:3. As can be seen from TABLE 4; total water, binder and aggregate weights of samples prepared on the basis of TS EN 196-1 was respectively 225:450:1350 grams. If water rates are taken into account, the amount of water contained in the alkali activators used for the activation was added to the mixture. In the last study, a plasticizer was used to increase the workability.

Table.5: Mechanical properties of Samples

Test Number	28-days Flexural Strength (MPa)	28-days Compressive Strength (MPa)
1	5,735	34,238
2	2,689	18,350
3	6,723	19,366
4	3,361	29,347

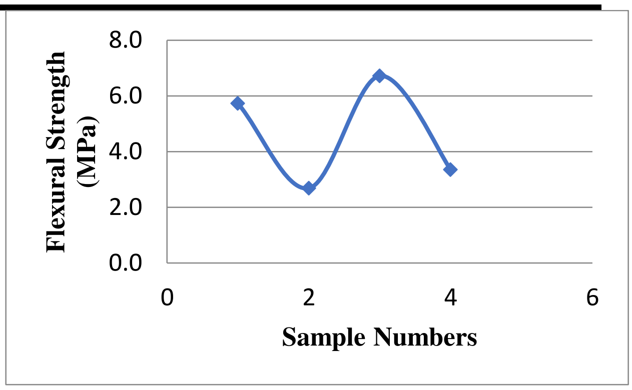

Fig. 1: Flexural strengths of the studies

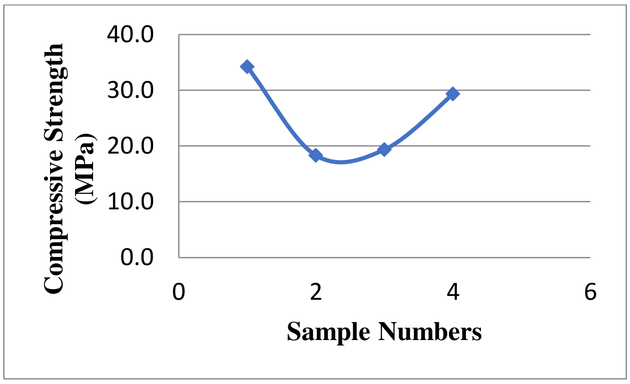

Fig. 2: Compressive strengths of the studies

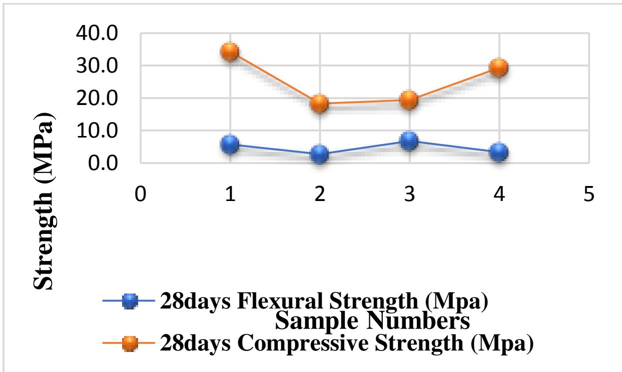

Fig. 3: Flexural and compressive strengths of the studies

Table.4: Quantities of studies carried out

		Sample 1	Sample 2	Sample 3	Sample 4
Water	Na_2SiO_4 (gr)	0	64	64	**0**
	NaOH (gr)	110	31	31	**110**
	Additional	115	130	130	**115**
	Water (gr)	225	225	225	**225**
	Total (gr)				
Binder	Fly Ash (gr)	0	112,5	112,5	**0**
	Blast furnace slag (gr)	450	337,5	225	450
	Cement (gr)	0	0	112,5	0
	Total (gr)	450	450	450	450
Alkali	Na_2SiO_4 (gr)	0	129	129	**0**
	NaOH (gr)	180	51	51	180
	Total (gr)	180	180	180	180
Aggregate	Rilem (gr)	1350	1350	1350	**1350**

Water/Binder	*W/C*	*0,5*	*0,5*	*0,5*	***0,5***
Plasticizer	***LABBED -779 (gr)***	***0***	***0***	***0***	***13***

The first study being the reference sample four different studies given in TABLE 4 were subjected to flexural and compressive strength tests according to TSE EN 196-1. Their test results are presented in TABLE 5. Fourth study is different from the reference sample in the direction of addition of the plasticizer as the content. The flexural and compressive strength of the study are shown in "Fig. 1", "Fig. 2" and "Fig. 3".

The results show that the addition of plasticizer reduces the flexural strength by %41.4 and the compressive strength by %14.29. Sample 2 was obtained from by the reference sample by removing the %25 blast furnace slag and adding the same amount of fly ash instead. When the sample is study 1 compared with Study 2, the flexural strength of the first study is decreased by %53,11 and the compressive strength by %46,40. In a similar way, study 3 obtained from the reference sample by adding 25% fly ash and 25% cement instead of blast furnace slag. The results showed that the flexural strength increased by %17.22 and the compressive strength decreased by %43.44. Comparing the test results of Study 2 and Study 3, the flexural and compressive strength of Study 2 increased by %150 and %5.54 respectively.

IV. CONCLUSION

It is seen that similar results are obtained according to the compressive strengths of traditional cement mortar if the compressive strengths in alkali activity are taken into consideration.

- This work has shown that blast furnace slag and fly ash, which are waste materials instead of cement, can be chemically activated and used. In this case, cement production, which accounts for 7% of the world's CO2 emissions, will prevent pollution by using alkali activation.
- With the use of factory waste such as fly ash and blast furnace slag, it will recycle to the environment.
- If we look at the bending strengths in alkaline activity, sudden changes are striking.
- In order to increase flexural strengths in alkaline-activated work, it is necessary to use it in the fibers.

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