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Experimental Notes on the Factors Affecting the Strength Behavior of Fly Ash Based Geopolymer Composites

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Abstract. Since Portland cement manufacturing processes are classified among the major reasons which are causing the global warming due the significant amount of carbon dioxide emitted every day. These facts have led the researchers to scrutinize an alternative which is more eco-friendly. In this paper, several experimental attempts were conducted to understand the effect of different of various factors on the strength behavior of fly ash based geopolymer composites.

INTRODUCTION

The rapid increase in the production of Portland cement in the world is causing greenhouse gas emissions. This situation leads to undesirable problems. A wide range of research is being conducted to produce an alternative to this situation. The production of environmentally friendly alternative materials has benefited from a large number of waste materials [1-4].

Geopolymers are one of the most important examples of alternative material production for portland cement by evaluating waste materials. Many researchers have conducted research on geopolymers that increase both strength and durability properties [5, 6].

As a consequence of the geopolymerization, waste materials will be evaluated, as well as greenhouse gas emissions will be reduced. With this feature, geopolymer is also a pioneer in the production of sustainable materials. The basic components required to form a geopolymer composite are a silica alumina source with chemical activators. These components form (Si-O-Al-O) bonds [7].

Since SiO_2 and Al_2O_3 are the basic oxides used in geopolymer production, various wastes containing these oxides and being aluminosilicate sources can be used in the production of geopolymers. These waste materials are materials such as fly ash, ground granulated blast furnace slag, metakaolin. Fly ash is considered to be the most widely used material in the construction sector not only in Turkey but also in the world. Fly ash has been used in numerous researches on geopolymer production in terms of microstructural and durability properties [8-12].

In addition to red clay, ground granulated blast furnace slag (GGBS) is a waste material that is the result of the production of pig iron. Ground granulated blast furnace slag is a material that is resistant to harsh environmental conditions such as fly ash and has high strength and environmental advantages for greenhouse gas emissions [13-15]. In fact, GGBS produces 80% less CO_2 than portland cement, and both are used in conventional portland cement and geopolymer synthesis [14].

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Al-Shathr et al. [16] tested different curing conditions on metakaolin-based geopolymer concrete. Sunlight curing, halogen curing, room temperature curing, water curing, wet burlap curing were made. Sunlight curing is a convenient and effective method at high temperatures of 35 ° C. Halogen curing provides a temperature of 50-55 ° C in cold weather. Water curing and wet sack curing are not the ideal solution for geopolymer mixtures.

Al-mashhadani et al. [17] studied the effect of slag as a calcium source on fly ash based geopolymer binders. A constant ratio of slag helps geopolymer for gaining strength.

Within the scope of this study, different cure conditions were tried by preparing fly ash mixtures at different rates with GGBS. Room temperature curing, high temperature oven curing, halogen curing and steam curing have been used to study. 7 and 28 days compressive and flexural strength tests were carried out on the obtained samples.

MATERIAL PROPERTIES AND EXPERIMENTAL PROCEDURE

The chemical analysis of fly ash (class F) and GGBS are described in Table 1. Fly Ash, Ground Granulated Blast Furnace Slag (GGBS), denotes FA and GGBS, respectively.

TABLE 1. Details of Fly Ash and GGBS (%).

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	Free CaO	Cl^-	LOI
FA	54.08	26.08	6.681	2.002	2.676	0.735	0.79	0.11	0.092	1.36
GGBS	40.55	12.83	1.10	35.58	5.87	0.18	0.79	___	0.0143	0.03

The alkali activator to be used in the production of the geopolymer is a mixture of sodium hydroxide and sodium silicate. Sodium silicate was supplied as a solution from Merck, while sodium hydroxide was provided in solid form. The molar ratio of the sodium silicate solution is 3.29 (SiO2 = 27%, Na2O = 8.2%). Using NaOH particles, 99% purity, 12M solution was prepared. In this study, sand according to BS EN 196-1..

In the current investigation, 3 different mixtures were prepared. Detailed information on these mixtures is given in Table 2. Mixtures of fly ash and GGBS were prepared at different ratios. While the mixture is being prepared, firstly the binder material is mixed dry. Sodium hydroxide solution (12 M) was prepared one day before the experimental mixture was made. On the working day, the mixture of sodium hydroxide and silicate solution was mixed with dry binder material. Binder material / alkali activator ratio was taken as 2: 1. Finally, the Rilem sand was added so that the binder material / aggregate ratio would be 1: 2.25. The mixture was exposed to vibration for 2 minutes after the mold was placed.

Three mixtures were prepared and 4 different curing conditions were applied. Specimens were exposed to room temperature, high temperature oven, halogen and steam curing and stored in closed containers until the test day. 7 and 28 days compressive and flexural strength tests were carried out on the obtained specimens.

TABLE 2. Mixing details of fabricated samples.

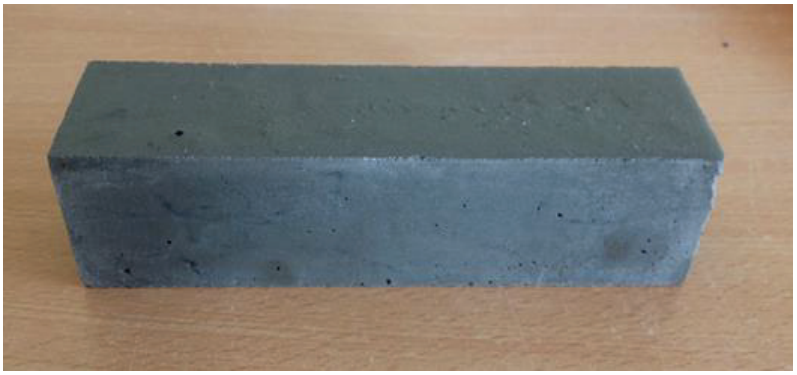
	FA	Slag	Sand	NaOH (12M)	Na_2SiO_3
Mix 1	450	-	1012.5	112.5	112.5
Mix 2	337.5	112.5	1012.5	112.5	112.5
Mix 3	225	225	1012.5	112.5	112.5

Particular attention should be given to lubricating the molds in sufficient quantities before placing the samples in the mold during experimental runs. Specimens placed in a high temperature oven are particularly damaged in the case of mold sticking (Fig. 1.a). In case of using grease, there is no problem in the samples (Fig. 1.b). Likewise, if the chemical feed is not put in the appropriate amount, problems arise in the samples (Fig. 1.c,d).

a)



b)



c)



d)



FIGURE 1. a) Damage to the sample as a result of not lubricated moulds, b) Grease oil-lubricated moulds result in the sample to come out of the mold properly, c) and d) Damage to samples that do not have an appropriate amount of alkali activator

RESULTS AND DISCUSSIONS

In the experimental studies made, the results of 7 and 28 days compressive and flexural strength of geopolymer specimens were examined. Fly ash and GGBS were used as waste materials. According to the obtained results, the highest strength results were obtained in the 1st mixture. The highest results in terms of curing were obtained at 80 ° C. When the compressive strength was obtained as 76.63 MPa in 28 day results, the flexural strength became 15.43 MPa. The amount of GGBS has reduced the compressive and flexural strength. As a result of curing conditions, the lowest results were obtained with halogen curing. The results of the 28 day flexural and compressive strength tests in the 3rd mixture with halogen curing are 5.38 MPa and 22.52 MPa, respectively. This is also compatible with previous work [16,18]. Compressive and flexural strength results are given in Table 3-4.

TABLE 3. Geopolymer mortar compressive strength results (MPa).

	80 °C oven curing (7days)	80 °C oven curing (28 days)	Room Temp. curing (7 days)	Room Temp. curing (28 days)	Halogen curing (7 days)	Halogen curing (28 days)	Steam curing (7 days)	Steam curing (28 days)
Mix 1	74.63	76.63	23.27	61.23	22.24	25.46	35.11	38.85
Mix 2	70.55	72.96	20.58	56.32	19.65	23.49	32.18	36.85
Mix 3	65.46	66.41	18.57	50.17	18.62	22.52	29.18	31.15

TABLE 4. Geopolymer mortar flexural strength results (MPa).

	80 °C oven curing (7 days)	80 °C oven curing (28 days)	Room Temp. curing (7 days)	Room Temp. curing (28 days)	Halogen curing (7 days)	Halogen curing (28 days)	Steam curing (7 days)	Steam curing (28 days)
Mix 1	14.25	15.43	6.73	12.66	6.18	7.23	8.46	9.41
Mix 2	13.28	14.45	6.06	11.58	5.43	6.55	7.72	8.10
Mix 3	12.16	14.04	5.54	10.76	4.43	5.38	6.21	7.18

CONCLUSIONS

In this study, it was tried to determine the ideal mixing ratio and curing conditions by looking at the 7 and 28 day results of fly ash-GGBS based geopolymer mortar mixtures. The results obtained are listed below.

- The highest results were obtained with blends made using a high temperature oven. The increase in temperature brought about an increase in compressive strength.
- As the amount of GGBS increased, the results of compressive strength and bending strength decreased.
- Halogen cure results are lower than other curing conditions. Room conditions are more sustainable and more economical as they spend less energy in curing than other curing conditions.

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