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GEOPOLYMERS BASED ON FLY ASH WITH THE ADDITION OF GRANULATED BLAST FURNACED SLAG

Ilhan Bušatlić#, 0000-0001-5003-0206,
Nadira Bušatlić, 0000-0002-7646-3752,
Nevzet Merdić, 0009-0008-6714-4064,
Nedžad Haračić, 0000-0002-9392-3298,
Lejla Mujezinović, 0009-0001-0091-5193,
University of Zenica, Zenica, B&H

ABSTRACT – Geopolymer is a type of inorganic polymer which hardens after being synthesized at ambient temperature. Geopolymers are synthesized by the reaction of poly-condensation of the geopolymer precursor and alkali activator. Ecologically, it would be more favourable to use industrial by-products since the hazardous waste is being taken care of. The most frequently used raw materials for geopolymer production are: kaolin clays, meta-kaolin, fly ash, blast furnace slag, fly ash and slag mixture, fly ash and meta-kaolin mixture and so forth. Fly ash from the Stanari Termal Power Plant, granulated slag from ArcelorMittal Zenica and quarc sand from Tuzla were used as initial raw material for the purpose of the study presented in this work. Based on the results obtained through research carried out in laboratory conditions at the Faculty of Engineering and Natural Sciences in Zenica and at the "Kakanj" Cement Factory, it can be concluded that fly ash from the TPP Stanari together with granulated blast furnace slag from ArcelorMittal Zenica can successfully use for the production of geopolymer. This test determined that the best compressive strength results were obtained by samples with a ratio of water glass/NaOH=2.0 and that the optimal heat treatment temperature was 60°C.

Keywords: Geopolymers, Fly Ash, Granulated Slag, Hardener, Compressive Strength.

INTRODUCTION

In the field of construction, cement is the main ingredient for the production of concrete. However, cement production requires large amounts of raw material. During the production of cement, the burning of limestone causes the emission of carbon dioxide into the atmosphere. [1] There are two sources of carbon dioxide emissions from cement production: the burning of fossil fuels to run the rotary kiln is the largest source, and the other is the chemical process of burning limestone. During the production of 1 ton of cement, approximately 1 ton of CO_2 is emitted into the atmosphere. If we consider that the world production of cement is about 4.18 billion tons, then it can be seen that during the production of cement, the same amount of CO_2 is released into the atmosphere. Of the total global annual CO_2 emissions, 5% is accounted for by cement production. [9,12]

corresponding author: ilhan.busatlic@unze.ba

Due to the increase in the consumption of concrete, there is also an increase in the production of cement, which results in an increase in environmental pollution and global warming. In addition to all greenhouse gases, carbon dioxide causes 65% of global warming. [10,11]

On the other hand, every year around 2.2 billion tons of construction waste are produced in the world. In addition to occupying huge areas for disposal of construction waste, this waste pollutes land, water and air. This paper presents one of the ways of using construction waste in the production of new materials.

Geopolymer is a type of inorganic polymer which hardens after being synthesized at ambient temperature. [5,6] Ecologically, it would be more favourable to use industrial by-products since the hazardous waste is being taken care of. The most frequently used raw materials for geopolymer production are: kaolin clays, meta-kaolin, fly ash, blast furnace slag, fly ash and slag mixture, fly ash and meta-kaolin mixture, slag and meta-kaolin mixture and so forth. [2,3,4]

EXPERIMENTAL

In this paper, geopolymer samples based on fly ash from the Stanari thermal power plant were tested. Fly ash from the Stanari thermal power plant, granulated blast furnace slage from ArcelorMittal Zenica, quartz sand from Tuzla, 12M NaOH solution and commercial water glass were used as materials. The samples were made with an alkali to fly ash ratio of 1. The $Na_2SiO_3/NaOH$ ratio ranged from 1; 1.5 and 2. The samples were prepared with different mass fractions of granulated blast furnace slag, namely 0, 10 i 20 %. The samples were thermally treated at geopolymerization temperatures of 60 °C. After that, the compressive strengths of the samples were tested after 1, 7 and 28 days.

The chemical analysis of the fly ash TPP Stanari is shown in Table 1, its granulometric composition is shown in Figure 1, and its XRD analysis is shown in Figure 2.

Table 1 Chemical composition of fly ash from TPP Stanari, B&H

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	MnO	TiO_2
Content (%)	44,21	19,06	8,56	20,98	2,33	1,78	1,55	0,058	0,70

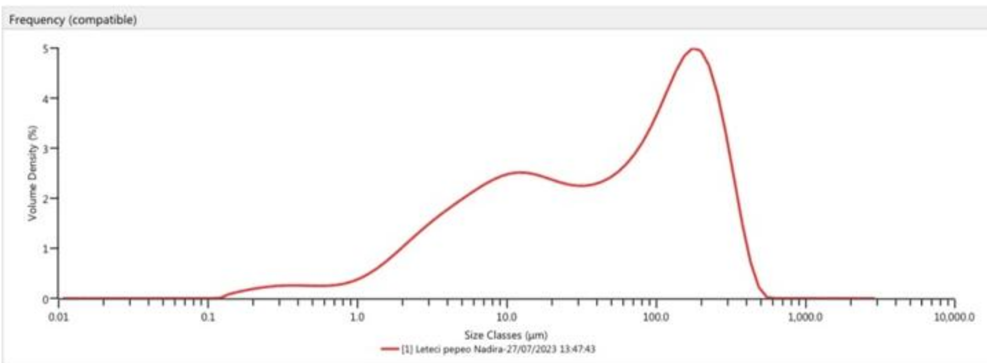

Figure 1 The granulometric composition of fly ash from TPP Stanari

It can be seen from the picture that the particle size of fly ash ranges from 0.14 to 550 µm. The part of particles whose size is over 200 µm is 15.84 %, the part of particles whose size is over 90 µm is 38.81 %, and the part of particles whose size is over 45 µm is 51.27%.

Figure 2 shows the XRD analysis of Stanari fly ash, which was performed at the Kakanj Cement Factory.

Based on the XRD analysis of fly ash, shown in Figure 2, it can be seen that the fly ash has a higher percentage of amorphous structure, but also contains a lower percentage of crystalline structure, which is indicated by several sharp quartz peaks. The proportion of the amorphous phase is 74.5%.

The chemical composition of the granulated blast furnace slag is shown in Table 2, while the granulometric composition is shown in Figure 3 and the mineral composition is shown in Figure 4.

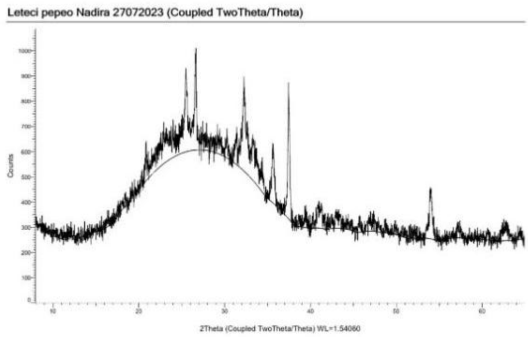

Figure 2 XRD analysis of fly ash

Table 2 Chemical composition of granulated blast furnace slag "ArcelorMittal" Zenica

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	GŽ
Content (%)	42,39	8,37	1,83	37,08	5,36	0,46	<o,01

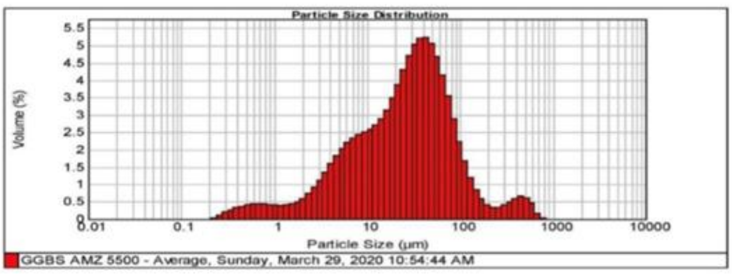

Figure 3 Granulometric composition of granulated blast furnace slag

It can be seen from the figure 3, that the particle size of granulated blast furnace slag ranges from 0.3 to 130 µm. The part of particles whose size is from 0.3 to 10 µm is about

25%, the remaining 65% is made up of particles with a size of 10 to 100 µm, and only about 10% of particles with a size of 100 to 130 µm, and it is visible that the largest part of particles size with 30 µm.

Based on the XRD analysis of the slag shown in Figure 4, it can be noted that there are no sudden peaks, i.e. of peaks that deviate from the others, therefore, we conclude that the slag has an amorphous structure.

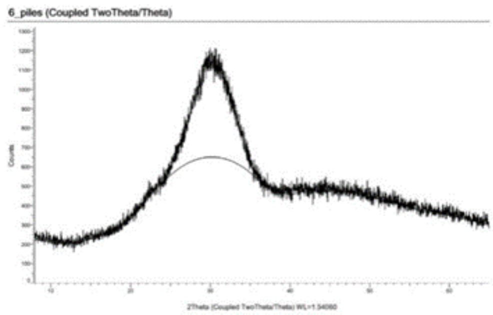

Figure 4 XRD analysis of granulated blast furnace slag

The chemical analysis of quartz sand is shown in Table 3, while the granulometric composition of quartz sand is shown in Table 4.

Table 3 Chemical analysis of quartz sand

Oxides	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	GŽ
Content (%)	96,45	1,00	0,23	0,68	0,24	0,22	0,79

Table 4 Granulometric analysis of quartz sand

Grain size (mm)	Iznad 2 mm	2 – 0,5	Ispod 0,5
Content (%)	4,4	93,5	2,1

Mixing ratios and markings of fly ash-based geopolymer samples are shown in the table 5.

Table 5 Ratios and markings of geopolymer samples

% GBFS	Sample label after 1 day	Sample label after 7 days	Sample label after 28 days	AA/FAGBFS	Na_2SiO_3/NaOH
0 %	1-60GT0,1	1-60GT0,7	1-60GT0,28	1	1.0
	1,5-60GT0,1	1,5-60GT0,7	1,5-60GT0,28	1	1.5
	2-60GT0,1	2-60GT0,7	2-60GT0,28	1	2.0
10 %	1-60GT10,1	1-60GT10,7	1-60GT10,28	1	1.0
	1,5-60GT10,1	1,5-60GT10,7	1,5-60GT10,28	1	1.5
	2-60GT10,1	2-60GT10,7	2-60GT10,28	1	2.0
20 %	1-60GT20,1	1-60GT20,7	1-60GT20,28	1	1.0
	1,5-60GT20,1	1,5-60GT20,7	1,5-60GT20,28	1	1.5
	2-60GT20,1	2-60GT20,7	2-60GT20,28	1	2.0

Homogenization of measured amounts of starting raw materials is done in a mixer for 5 minutes, after which the obtained mixture is transferred into molds and subjected to vibrations on a vibrating table for 5 minutes in order to compact the sample. The binding process is exothermic so the samples must be hermetically closed. After 24 h, the samples were taken out of the mold and wrapped in nylon bags. The wrapped samples were kept in the oven for 24 hours at activation temperatures of 60 °C. After the thermal treatment, the samples were taken out of the bags and left to stand in the air until testing the compressive strengths after 1, 7 and 28 days.

RESULTS AND DISCUSSION

After the samples were prepared, the compressive strength of the geopolymer was tested after 1, 7 and 28 days. The results of the obtained compressive strengths are shown in Table 6 and Figure 5.

Table 6 Compressive strength of samples after 1, 7 and 28 days

Samples	Compressive strength (Mpa)		
	1 day	**7 days**	**28 days**
1-60GT0	14,1	22,5	31,22
1,5-60GT0	19,48	26,08	29,93
2-60GT0	24,81	30,38	31,58
1-60GT10	10,49	14,16	15,60
1,5-60GT0	14,62	20,04	28,84
2-60GT10	18,13	25,00	31,61
1-60GT20	8,16	10,97	14,78
1,5-60GT20	15,38	20,61	26,21
2-60GT20	21,15	25,45	29,06

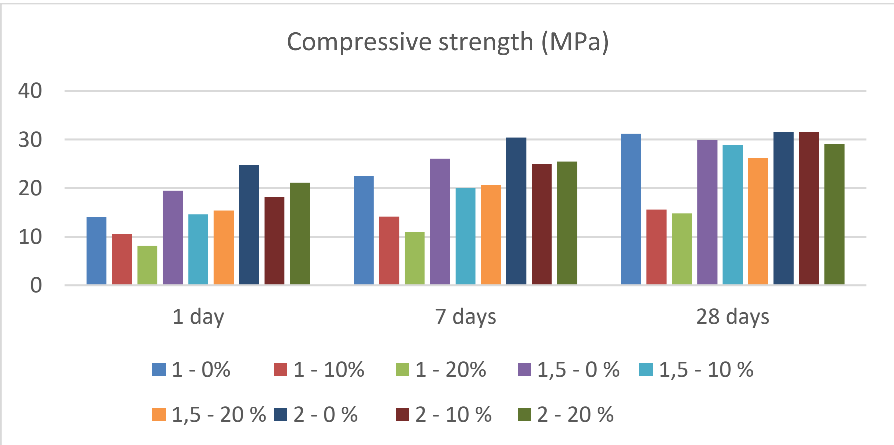

Figure 5 Dependence of compressive strength on percentage addition of granulated blast furnace slag and Na_2SiO_3/ NaOH ratio

CONCLUSION

The following can be concluded from all of the above:

Geopolymer samples based on fly ash TPP Stanari with the addition of granulated blast furnace slag from ArcelorMittal Zenica gave satisfactory results. These samples proved to be stable in all stages of geopolymer production, from the stage of preparation of fresh geopolymer paste and its aging for 24 hours, through heat treatment to testing of compressive strength. Due to the above, it can be concluded that Stanari fly ash and granulated blast furnace slag from ArcelorMittal Zenica can be used for the production of geopolymers. Increasing the content of addition of granulated blast furnace slag to fly ash reduces the compressive strength of geopolymer. Increasing the Na_2SiO_3/ NaOH ratio increases the compressive strength of the geopolymer. Namely, the samples without the addition of granulated blast furnace slag have the highest value of compressive strength. If we add blast furnace slag, we have to increase the Na_2SiO_3/ NaOH ratio in order to obtain higher compressive strength values. Samples made with a ratio of VS/NaOH = 2.0, treated at a temperature of 60°C, show the highest compressive strengths after 28 days.

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