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S/S TREATMENT FOR ALUMINUM SLAG WASTE USING FLY ASH-BASED GEOPOLYMERS

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Abstract
Fly ash(FA) is one of the four by-products of coal combustion in thermal power plant boilers, accounting for 40–90% of the total amount of by-products. Due to its physico-chemical properties and applied treatments, FA utilization offers environmental, economic, and sustainable benefits for waste management. The aim of this paper is to investigate the influence of aluminum slag waste (ASW) addition on the mechanical properties of FA-based geopolymers primarly prepared to evaluate the potential for ASW stabilisation/solidification. The experimental part was conducted under define parameters required for geopolymerisation: S/L ratio (1), NaOH concentation (10 M), mass ratio Na_2SiO_3/NaOH (1.5) with varying ASW contents from 1% to 10%. EN 12457-2 leachability test was performed with and without ASW loaded geopolymers. Experimental results indicate that the addition of ASW reduces the compressive strength of FA-based geopolymers while the leachablity test confirmed that ASW-loaded geopolymers meet the leaching limits defined for stable non-reactive hazardous waste.

***Keywords**: Fly ash, geopolymers, aluminum slag, stabilization/solidification*

1. INTRODUCTION

Montenegro as an EU candidate has the obligation to establish an integrated waste management system which is according to the European Commission considered one of the priority goals on the path to EU accession. If the best economic and environmental waste management solution is to be achieved in Montenegro in the future it is important to implement environmentally friendly techniques for processing waste materials of various origins. The Thermal power plant "Pljevlja" annually consumes an average of 1.6 million tons of lignite coal to produce electricity and thermal energy of which 20–30% is generated as by-products 480.000 tons of fly ash and 320.000 tons of slag [1]. As a geopolymer binder in the solidification/stabilization process causes physical and chemical changes in the structure of the waste material leading to the immobilization of pollutants and reducing their migration potential in different environmental compartments [2,3]. The utilization of fly ash through geopolymerization results in a reduction of CO_2 emissions by enabling the process to be carried out under milder conditions compared to the production of Portland cement (OPC) while also decreasing the amount of ash that would otherwise be disposed of in landfills without pretreatment [4].

The aim of this work is to utilize fly ash as an eco-friendly binder for geopolymer synthesis and to evaluate the application of fly ash-based geopolymers in S/S treatment with varying dosages of ASW. Leachability test, EN 12457-2, was used to asses the S/S potential of fly ash-based geopolymers.

2. EXPERIMENTAL

Fly ash was collected from the coal fired power station in Pljevlja and ASW from the Aluminum plant in Podgorica. Synthesis of fly ash-based geopolymer (FO) was performed by mixing of fly ash with an alkaline activator in a solid to liquid ration 1. Alkali activator was prepared by mixing of 10 M NaOH and Na_2SiO_3 solution (commercial water glass) in a mass ratio of 1.5. Fly ash based geopolymers contaminated with slag (ASW) were prepared by adding ASW to the starting mixture by fly ash replacement with a 1- 10% to the total solid content. First aluminum slag was mixed with alkali activator and then, fly ash was added. Then, the both, FO and ASW, geopolymer mixtures were poured into cylindrical plastic molds (28× 60 mm) sealed with a lid to minimize water evaporation. The prepared samples were oven-dried at 65 °C for 48 hours. The solid specimens were allowed to cool to room temperature, removed from mould and left to rest for a period of 15 days before any testing was performed. After 15 days, in order to evaluate the compressive strength, the surfaces of three specimens per mixture were polished flat and tested using a compression testing machine. The fragment of geopolymers remained after the strength testing were used to assess the immobilization potential of metals and chloride from aluminum slag in accordance with the EN 12457-2 leaching procedure. Metal content in filtrate remained after the leaching test was analyzed using an Ametek Spectro Arcos FHE12 Spectrometer Analyzer while the content of chloride was analyzed by argentometry titration.

3. RESULTS AND DISCUSSION

3.1 Influence of ASW dosage on compressive strenght

The figures of obtained FO and ASW geopolymer samples with a different dosage of aluminum slag are given in Fig. 1.

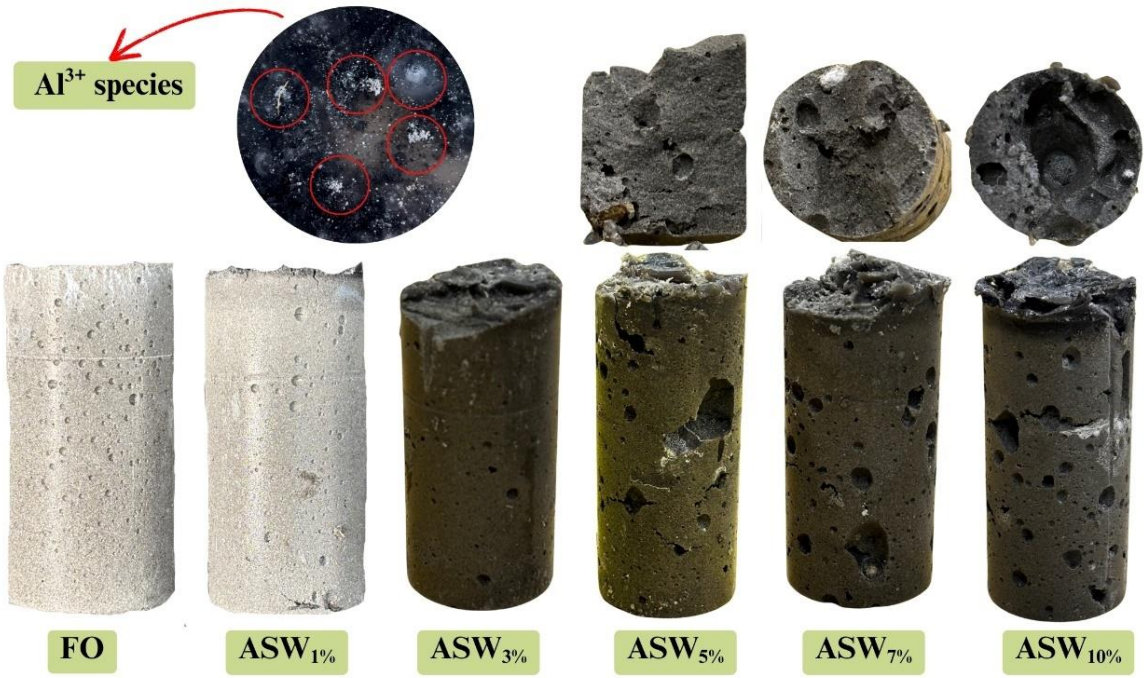

Figure 1. FA-based geopolymers with ASW (1-10%)

The results have shown that optimal dosage of aluminium slag was up to 3 %. Further increase of slag addition caused the highly porous and britle structure with a weak mechanical properties. Geopolymer samples containing more than 3% of aluminum slag had a tendency to crack during

the drying process and these samples did not meet the criteria for further mechanical property testing. Thus, only geopolymers containing the 1 and 3 % of aluminum slag were used for further investigation. Influence on different ASW dosages (1 and 3%) on compressive strenght of fly ash based geopolymers are presented in Figure 2.

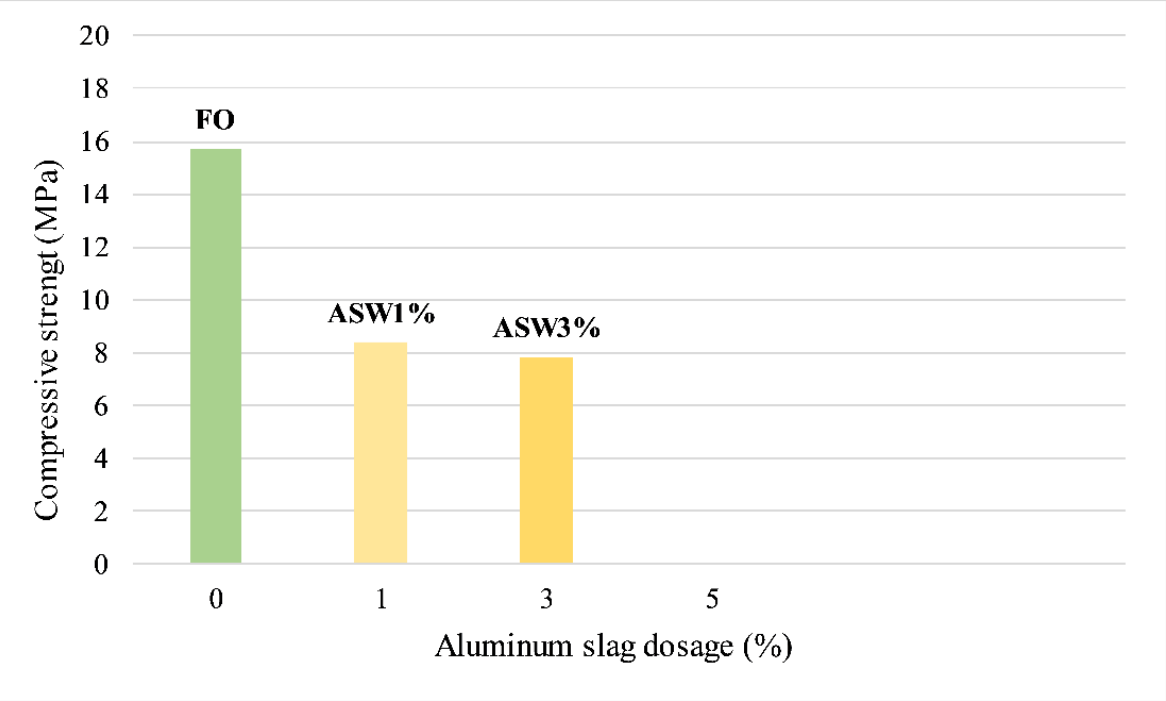

Figure 2. Influence of ASW dosage on compressive strenght

As shown in Figure 2. the highest compressive strength (15.71 MPa) displayed the FA-based geopolymer (FO). The replacement of fly ash with slag led to a decrease in compressive strength of geopolymers. The geopolymers with a 1% and 3 % of slag (denoted as ASW1% and ASW3% respectively) displayed the strength of 8.39 MPa and 7.85MPa, respectively. The introduction of slag into fly ash based geopolymer lead to the weakening of geopolymer structure due to the increase of porosity caused by to the release of hydrogen during the dissolution of aluminum from AS in the alkali activator as presented by equations (1) and (2), where Me_{1A} represents sodium or potassium [5]:

$$2Al + 2Me_{1A}OH + 6H_2O \rightarrow 2Me_{1A}Al(OH)_4 + 3H_2\uparrow \quad (1)$$

$$2Al + 2NaOH + 6H_2O \rightarrow 2Na[Al(OH)_4] + 3H_2\uparrow \quad (2)$$

3.2 Leaching behavior of FA/ASW geopolymers

The efficiency of S/S of aluminum slag through geopolymerization process was evaluated using EN 12457-2 compliance tests, comparing the metals and chloride concentration in EN 12457 leachates with limits established by EULFD (European Landfill Directive) [6].

The metal and chloride release, from ASW1% and ASW 3% geopolymers structure according the EN 12457-2 leaching test is shown in Table 1. As shown in Table 1, the concentrations of metal and Cl released from FO and ASW1% and ASW3% geopolymers meet the criteria for waste acceptance in non-hazardous landfills.

Table 1-Results of EN 12457-2 leaching test with limit values for landfill waste acceptance criteria

Element (mg/kg)	Inert waste	Stable Non-Reactive Waste (in NH class)	Hazardous waste	FO	$ASW_{1\%}$	$ASW_{3\%}$
As	0.5	2	25	7.68	8.51	9.08
Ba	20	100	300	0.239	0.165	0.547
Cd	0.04	1	5	<0.0006	0.001	0.016
Cr	0.5	10	70	0.337	0.342	0.581
Cu	2	50	100	0.138	0.047	0.200
Hg	0.01	0.2	2	0.03	0.032	0.002
Mo	0.5	10	30	0.839	0.90	1.26
Ni	0.4	10	40	0.107	0.116	0.219
Pb	0.5	10	50	0.227	0.343	0.613
Sb	0.06	0.7	5	0.193	0.401	0.852
Se	0.1	0.5	7	0.894	1.52	2.29
Zn	4	50	200	0.144	0.071	0.314
Cl	800	15000	25000	2500	3750	2500

4. CONCLUSION

Fly ash based geopolymers were used for S/S treatment of aluminum slag waste. Fly ash replacement with an aluminum slag led to the weaking of geopolymer structure. The structure of geopolymers with a content of slag more than 3 % did not match criteria for mechanical testing. Pure fly ash based geopolymers reach the compressive strength of 15.71 MPa and fly ash replacement with a slag in a quantity of 1% to 3% lead to the decreased compressive strength to 8.39 MPa to 7.85 MPa, respectively. The results of EN 12457-2 leaching test have shown that FO, $ASW_{1\%}$ and $ASW_{3\%}$ geopolymers meet the EULFD criteria for non- hazardous waste.

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