

Original Research

**STRENGTH AND MICROSTRUCTURE OF FLY ASH BASED GEOPOLYMERS
CONTAINING WASTE PLASTIC**

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Abstract

This paper investigated the properties of fly ash based geopolymers containing waste plastic (high-density polyethylene (HDPE)). Influence of fly ash substitution with a 30% of plastic waste on the compressive and flexural strength unit weight and microstructure of geopolymers was investigated. The results have shown that plastic dosage led to the wakening geopolymer structure, i.e. impairs mechanical properties. The positive effect of plastic waste addition is reflected in the decrease of unit weight which is beneficial with respect of the structure load. Microstructural investigations have shown the particle of plastic waste embedded into the reaction product of geopolymerisation i.e. into the alumino-silicate gel.

Keywords: fly ash, high-density polyethylene, (HDPE) geopolymer, unit weight, strength.

INTRODUCTION

Publicly accessible information from Montenegro indicates that the thermal power station in Pljevlja disposed of around 360 metric tonnes of fly ash in 2020, with an estimated 12 million tonnes of fly ash already deposited at the Maljevac landfill in Pljevlja [1]. Thus, the valorisation of this waste material is of great importance from the standpoint of environment protection. Currently, extensive research is caring out into the field of fly ash valorisation in a new environmentally friendly building material.

Moreover, plastic pollution has become one of the most pressing ecological issues, as rapidly increasing production of disposable plastic products overwhelms the world's ability to deal with them. Data from 2021 indicate that in Montenegro, plastic waste constitutes 15.3%

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of the total solid municipal waste and that 75.65 kg of plastic waste is generated per capita in Montenegro [2]. It represents a serious hazard for the ecosystem which also need to be solved.

Valorisation of fly ash using geopolymerization technology is widely investigated in a pass decade. Geopolymerization is a relatively new technology that can transform natural or waste aluminosilicate materials (fly ash or metakaolin), with alkali activation, into an amorphous to semi-crystalline inorganic polymer – the geopolymer [3–5]. The process includes several steps: dissolution of the starting material in a highly alkaline silicate solution and formation of aluminate and silicate monomeric species, formation of Si and/or Si-Al oligomers in an aqueous solution, condensation of oligomeric species in an aluminosilicate network - geopolymer, and hardening. Sodium silica solution is mainly used as activator in the geopolymerization process.

The aim of this paper was to investigate simultaneous valorisation of fly ash and plastic waste (high-density polyethylene (HDPE)) through geopolymerisation process into the new materials with a possible application in the civil engineering. This approach is of great importance from the standpoint of environment protection which will contribute to reintroducing waste into the production cycle instead of disposing of it in landfills.

MATERIALS AND METHODS

Fly ash was supplied form coal fired power station in Pljevlja (Figure 1a)) and plastic waste (HDPE) from the MONTWAY LLC Podgorica (Figure 1b)).

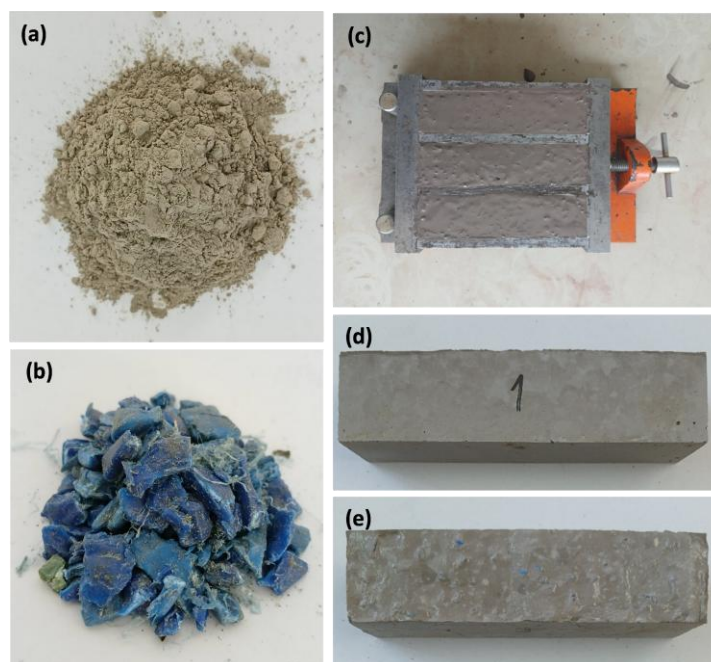


Figure 1 a) Flay ash; b) Waste plastic HDPE; c) Casted fly ash based geopolymer; d) the hardened fly ash based geopolymer without and e) with waste HDPE

Fly ash based geopolymer were prepared by mixing of fly ash with alkali activator at solid to liquid (S/L) ratios of 1.4. Alkali activator was prepared by mixing of 7M NaOH solution

and Na_2SiO_3 solution (commercial water glass) in a mass ratio of 1. Prepared geopolymers were casted in mould ($40 \times 40 \times 160$ mm) (Figure 1c)), covered with a nylon and cured in the oven at the temperature of 65°C for a period of 48 h. After 7 days, the samples were removed from mould, and rest at the room condition for additional 2 weeks and conducted for mechanical testing (testing for compressive and flexural strength). Before mechanical testing, the samples were weighted and unit weight (kg/m^3) was calculated.

Fly ash based geopolymer containing HDPE was prepared by adding HDPE to the starting mixture by fly ash replacement with 30% to the total solid content following the same procedure. The fragments remained after the testing of mechanical properties were used for a microstructural analysis.

Microstructural investigations were carried out using the FEI Helios NanoLab 660 SEM/FIB dual beam system, equipped with the EDAX energy dispersive X-ray spectrometer (EDS).

RESULTS AND DISCUSSION

Sample of fly ash based geopolymers without HDPE addition is given in Figure 1d) and the figure of geopolymer sample synthesized with 30 % of waste HDPE is given in Figure 1e). The results of mechanical testing were given in the Figure 2.

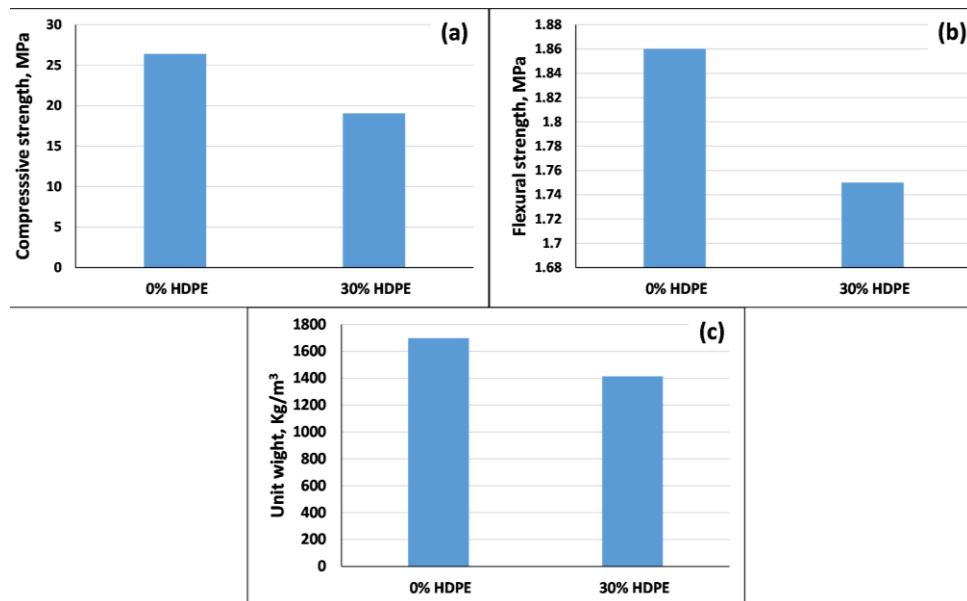


Figure 2 Influence of plastic waste addition on the a) compressive strength; b) flexural strength and c) unit weight of geopolymer

It is evident that, addition of waste plastic led to the weakening of fly ash based geopolymers. Fly ash based geopolymer synthesized without waste plastic, reach the compressive strength of 26.41 MPa while fly ash substitution with 30% of waste HDPE led to the decrease of compressive strength to the 19.06 MPa (Figure 2a)). Likewise, flexural strength of geopolymers with 30% waste HDPE also decreases from 1.87 MPa to 1.75 MPa (Figure 2b)). The benefit of HDPE addition is reflected in a decrease of unit weight of fly ash

geopolymers from 1698 kg/m³ to 1414 kg/m³ (Figure 2c)) which is important from the standpoint of application of these materials in the practice. Reduction of the unit weight of building materials is important because it reduces the self-weight of the structure and the load on the construction and foundations.

The results of SEM/EDS analysis are given in the Figure 3 and Table 1. The SEM photography clearly show the particle of plastic waste embedded in a geopolymer binder. The results of EDS analysis taken from the geopolymer binder area denoted with a red cross indicate the high content of silicon, aluminium and oxygen (Table 1) *i.e.* the presence of alumina-silicate gel, as the major binding phase generated due to the geopolymerisation reaction [6].

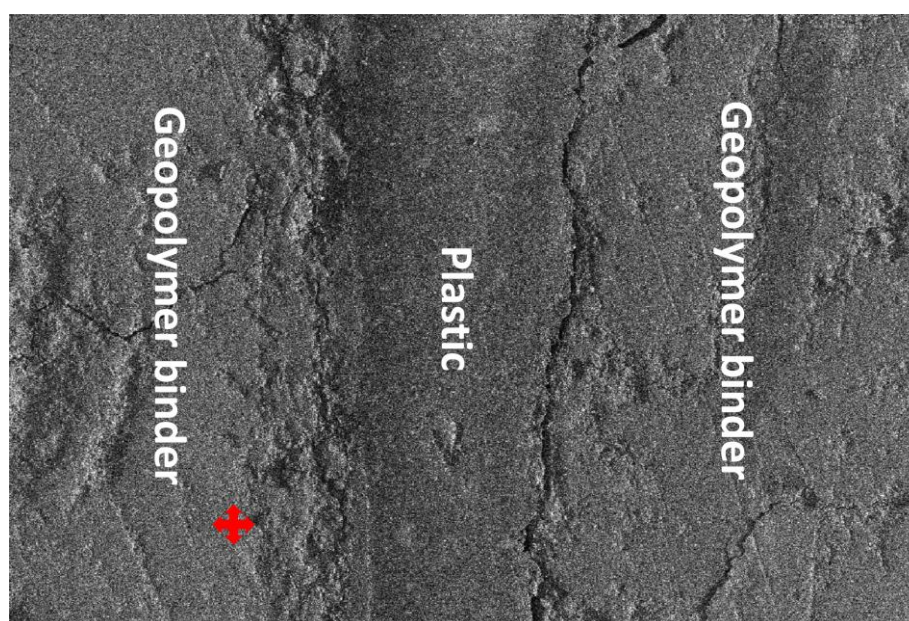


Figure 3 SEM photography of fly ash based geopolymer containing plastic (HDPE) waste

Table 1 The results of EDS analysis taken from the geopolymer are in Figure 3, denoted with red cross

Element	wt. %
Oxygen	38.83
Aluminium	10.78
Silicon	23.70
Iron	3.10
Calcium	8.90
Chromium	0.08
Potassium	2.81
Phosphorous	4.58
Sulphur	1.12
Magnesium	0.8
Sodium	4.94
Titanium	0.25
Vanadium	0.11

CONCLUSION

The results have shown that fly ash based geopolymers can be synthesized with 30% of waste (HDPE) plastic. Although, substitution of fly ash with 30% of HDPE lead to the decrease of compressive and flexural strength of fly ash based geopolymers for a 7.4% and 5.9%, respectively, they can be used in a civil engineering. The benefit of substituting ash with 30% plastic is reflected in a decrease of unit weight of fly ash based geopolymers. Microstructure of fly ash based geopolymer containing the plastic waste is consisting of plastic embedded in a geopolymer binder. Existence of geopolymer binder is confirmed by EDS analysis which indicated presence of alumina-silicate gel.

ACKNOWLEDGEMENT

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