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VALORIZATION OF FLY ASH AND PLASTIC WASTE USING GEOPOLYMERIZATION TECHNOLOGY

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Abstract
This paper aimed to investigate the possibility of synthesis of geopolymers based on the fly ash with the addition of plastic waste (high-density polyethylene (HDPE) and polypropylene PP). Influence of plastic waste dosage and time of curing and solid to liquid (S/L) ratio on the compressive strength of fly ash-based geopolymes were investigated.

The results have shown that fly ash-based geopolymers synthesized with plastic waste can be successfully prepared under the S/L ratio of 0.9 and 1, mass ratio of alkali activator (Na_2SiO_3/NaOH) of 1, and plastic dosage up to 30%. The highest strength displayed the geopolymers synthesized by the fly ash replacement with plastic waste of 10 %, cured for 48 h at S/L ratio of 0.9. Generally, flay ash-based geopolymer with the addition of HDPE reaches a higher strength in comparison to those prepared with PP under the same conditions of synthesis.

***Keywords**: Fly ash, geopolymers, plastic waste, high-density polyethylene (HDPE), polypropylene (PP), compressive strength*

1. INTRODUCTION

In line with the Paris Agreement from 2016. year, global warming must be limited to 1.5 ºC to minimise the greenhouse effect [1]. So, it is necessary to minimise anthropogenic inputs of carbon dioxide into the atmosphere from major sources, including the cement production industry. Approximately 0.9 tonnes of carbon dioxide are released in the production of one tonne of cement [2]. It is estimated that global cement production contributes a significant 8% to total carbon dioxide emissions [3], and its replacement with secondary raw materials could reduce the annual global carbon dioxide emissions by up to 1.3 gigatons [4]. From this point of view, fly ash, the waste material from coalfired power stations, has been extensively researched in the past two decades as a partial or full replacement for cement binder in construction.

The innovative technology known as geopolymerization enables the utilization of fly ash to produce new eco-friendly building materials known as geopolymers, which are currently considered an alternative to cement binders. Geopolymers are produced under alkali activator action of natural minerals, or solid industrial waste rich in silicon and aluminium. These materials are environmentally friendly binders due to their lower carbon dioxide emissions from the

manufacturing process and elimination of natural resources consumption, while the compressive strength and durability are comparatively high.

On the other hand, current levels of plastic usage and disposal at the global level generate serious environmental problems since it is a persistent organic pollutant. Every year, millions of tons of plastic end up in the environment, posing environmental, economic, health and aesthetic problems. Since plastic waste can also be utilized in building materials [5], this research aimed to investigate the possibility of co-valorisation of fly ash and plastic waste (high-density polyethylene (HDPE) and polypropylene (PP)) through the geopolymerization process.

2. EXPERIMENTAL

Fly ash was supplied from a coal fired power station in Pljevlja and plastic waste (PP and HDPE) from the MONTWAY Podgorica. Figures of source materials are given in Figure 1 (a-c). Fly ash-based geopolymers containing plastic waste PP (denoted as FPP) and HDPE (denoted as FHDPE) were prepared by adding PP and HDPE to the starting mixture by fly ash replacement with a 10-30% to the total solid content. First, fly ash was mixed with alkali activator at solid to liquid (S/L) ratios of 0.9 and 1, and then, plastic waste was added. Alkali activator was prepared by mixing 7M NaOH solution and Na_2SiO_3 solution (commercial water glass) at a mass ratio of 1:1. Prepared geopolymers were casted in a plastic mould, sealed with a lead and cured in the oven at a temperature of 65 °C for a period of 24 h and 48 h. After 7 days, the samples were removed from mould and tested for compressive strength.

3. RESULTS AND DISCUSSION

The initial components (fly ash, PP, HDPE) and resulting geopolymers are shown in Figure 1 (a–e), and the influence of plastic waste dosage on compressive strength of fly ash-based geopolymers is given in Figure 2.

The results have shown that fly ash-based geopolymers can be synthesized with both PP and HDPE plastic waste addition (Figure 1). The results presented in Figure 2 generally show that prolongation of curing time from 24 h to 48 h leads to the strengthening of the geopolymeric structure, regardless of the type of plastic added to the geopolymeric mixture. Geopolymers prepared with a mixture of fly ash and HDPE reach a higher compressive strength in comparison to geopolymers prepared with the addition of PP plastic. The highest strength (13.5 MPa) exhibited the fly ash-based geopolymers prepared with the addition of 10% HDPE. The increase of fly ash replacement with HDPE to 30% led to the weakening geopolymeric structure and strength decrease to 6.2 MPa. The geopolymer prepared with a PP follows the same pathway of strength change upon the PP addition. The highest strength of geopolymer prepared with PP was obtained for geopolymers containing 10% PP (11.5 MPa), and the lowest strength (4 MPa) was obtained for geopolymers containing 30% of PP.

The influence of S/L ratio on the strength of fly ash-based geopolymers containing plastic waste (PP and HDPE) is given in Figure 3. The influence of S/L ratio on the strength of geopolymers is only evident at the plastic waste dosage of 10%. Geopolymers containing 10% plastic waste prepared at the S/L ratio of 0.9 reach higher strength in comparison to those synthesized at S/L=1. When a higher plastic waste dosage was applied, practicaly there was no influence of S/L ratio on the strength of geopolymers.

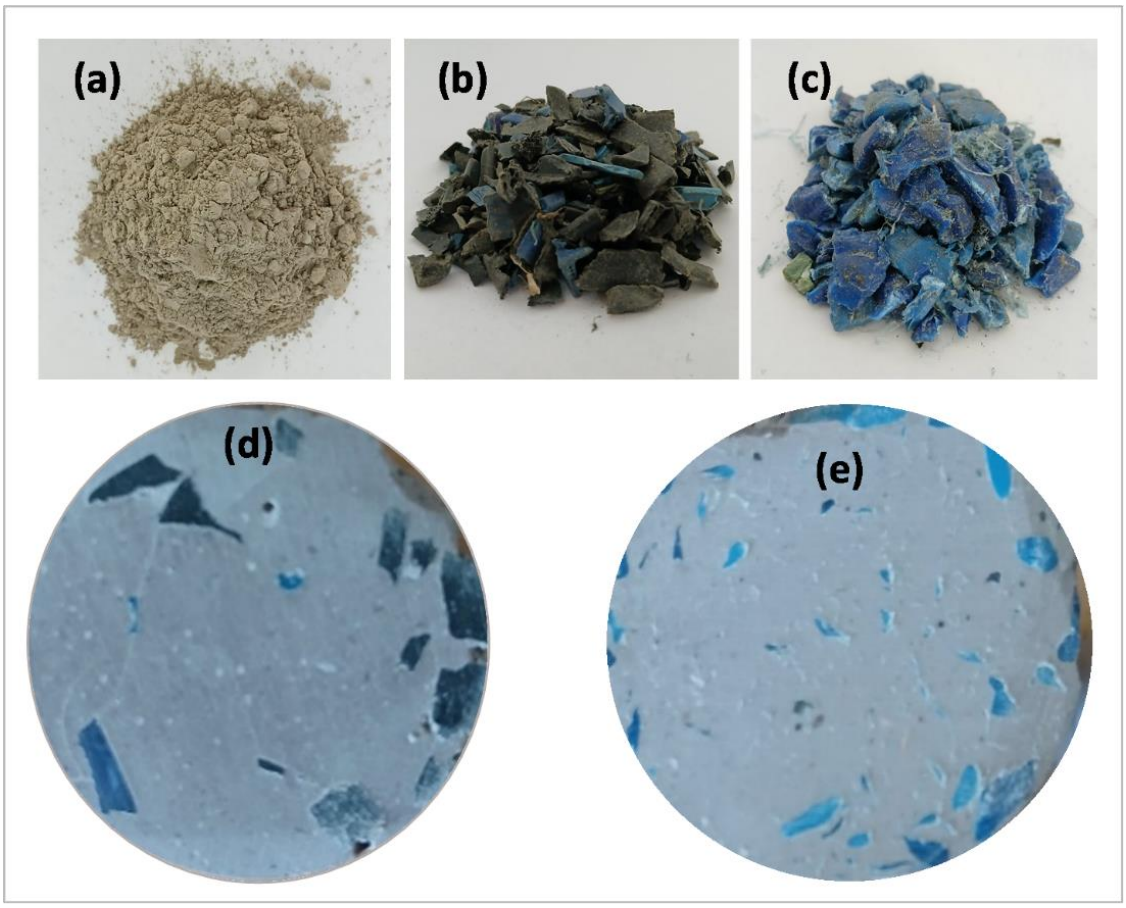

Figure 1. Figures of source materials (a) - fly ash, (b) - PP, (c) - HDPE, and fly ash-based geopolymers with (c) - PP and (d) - HDPE

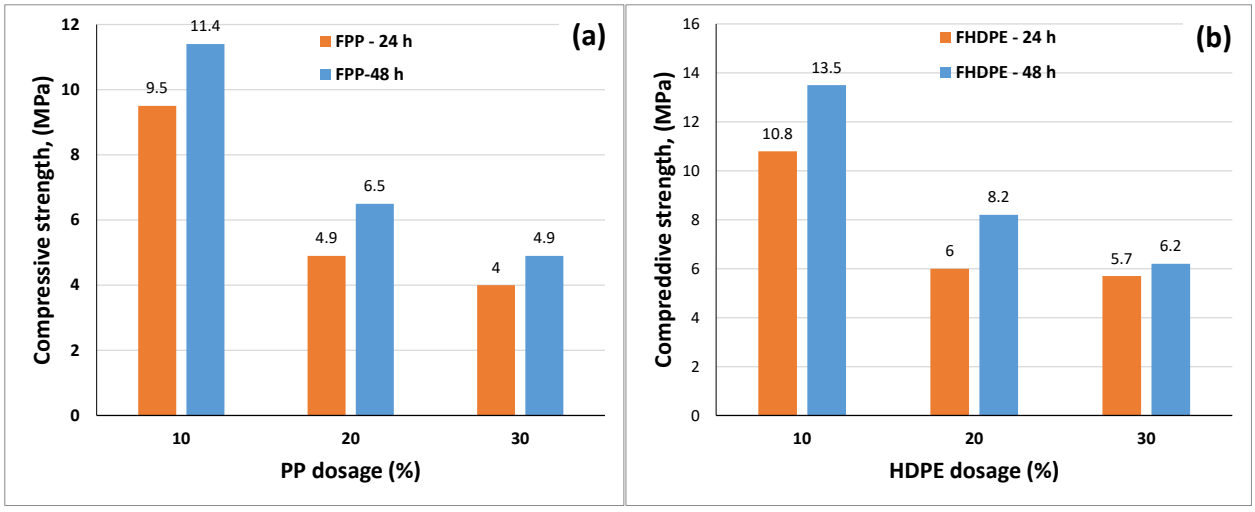

Figure 2. Influence of plastic waste dosage FPP (a) and FHDPE (b) on compressive strength of fly ash-based geopolymers at S/L=0.9

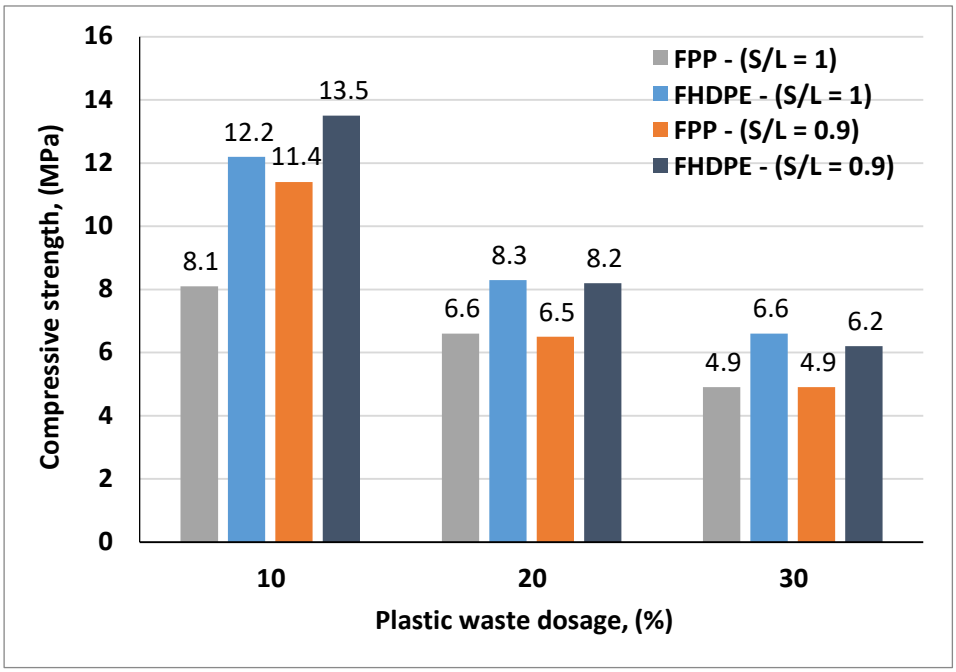

Figure 3 - Change of compressive strength of fly ash-based geopolymers prepared at different S/L ratios and plastic waste dosage

4. CONCLUSION

Fly ash-based geopolymers were synthesized with the addition of plastic waste (PP and HDPE) up to 30 %. The highest strength was exhibited by the geopolymers synthesized with a 10% replacement of fly ash with plastic waste. Geopolymers synthesized with HDPE were generally stronger than those prepared with PP. The highest strength of fly ash-based geopolymers with plastic waste was achieved at the S/L ratio of 0.9. Prolongation of the time of curing from 24 h to 48 h slightly strengthens the geopolymers' structure.

ACKNOWLEDGEMENTS

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