EGU22-2411
https://doi.org/10.5194/egusphere-egu22-2411
EGU General Assembly 2022

MSWI fly ash incorporation into acid-based geopolymer: reactivity and performance impact

Davide Bernasconi[1], Alberto Viani[2], Petra Mácová[2], Lucie Zárybnická[2], Caterina Caviglia[1], Enrico Destefanis[1], Simone Bordignon[3], Roberto Gobetto[3], and Alessandro Pavese[1]
[1]Earth Sciences Department, Università degli Studi di Torino, Turin, Italy (davide.bernasconi@unito.it)
[2]Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences, Centre Telč, Prosecká 809/76, Praha 9, 190 00, Czech Republic
[3]Chemistry Department, Università degli Studi di Torino, Turin, Italy

Municipal solid waste incineration fly ash (MSWI-FA) is one of the solid by-products of MSWI treatment, accounting for about 1–3% of the total incinerated waste. FA forms in the plant purification system and bears important amount of heavy metals and salt (chloride and sulphate), therefore it is considered as hazardous waste (Bernasconi et al, 2022). For this reason, FA is required to undergo stabilization/inertization treatment (one of the most common is water washing), before being landfilled or used as secondary/supplementary raw materials. In this latter case, many studies have evaluated the incorporation of FA into alkali silicate-based geopolymer. This material is obtained by the reaction between an aluminosilicate source (metakaolin, MTK) and alkali hydroxide (NaOH, KOH), to obtain polymer-like condensation product (Wang et al, 2019). This material is characterized by higher durability and greenness with respect to the conventional Portland cement (OPC), thus gaining interest recently as a promising partial substitute to OPC. On the other hand, much less attention has been focused on acid-based geopolymer, in which the alkali hydroxide is substituted by phosphoric acid, thus producing an Al-O-P/Si-O-P polymeric matrix (Wang et al, 2019). This material has displayed better performance than the traditional alkali-silicate geopolymer, in terms of corrosion resistance (Wagh et al, 2011), thermal stability (Celerier et al, 2019) and mechanical strength. However, there are also some drawbacks, mainly related to the expensive cost of the starting materials, since MTK is obtained by high-temperature (750°C) calcination of kaolinite. The introduction of FA would be economically beneficial both by reducing the amount of MTK needed and providing a destination for a waste residue which otherwise would require important management costs.

In this work, (previously washed) FA partial replacement of MTK has been tested in the phosphate-based geopolymer formulation, up to 50 wt%. Different synthesis conditions have been evaluated, in terms of Al/P molar ratio, liquid-to-solid ratio and curing temperature. The resulting reaction products have been investigated by a combined analytical approach, involving spectroscopies (ATR-FTIR and Solid-state NMR) and powder X-ray diffraction techniques, while their morphology was inquired by SEM-EDS analysis. Moreover, compressive strength tests have been employed to evaluate the mechanical properties, which demonstrated the good performances of FA blended phosphate-based geopolymers, with compressive strength values over 30 MPa.

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