Investigation of Municipal Solid Waste Fly Ash Reactivity into Magnesium Phosphate Cement

Davide Bernasconi1, Alberto Viani2, Lucie Zárybnická2, Gangadhar Das3, Elisa Borfecchia4, Caterina Caviglia1, Enrico Destefanis1, Roberto Gobetto4, and Alessandro Pavese1

1Earth Sciences Department, University of Turin, Turin, 10125, Italy
2Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences, Centre Telč, Prosecká 809/76, Praha 9, 190 00, Czech Republic
3ELETTRA Sincrotrone Trieste S.C.p.A., Basovizza, Italy
4Chemistry Department, University of Turin, Turin, 10125, 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, few studies have evaluated the incorporation of waste residues into magnesium potassium phosphate cements (MKPCs), mainly focusing on coal fly ash and grounded blast furnace slag (Gardner et al., 2015; Xu et al, 2017). They represent an example of chemically-bonded ceramics, in which the hardening occurs at room temperature through the acid-base aqueous reaction between an alkaline magnesia source (MgO) and a phosphate source (KDP, KH2PO4), according to the following chemical equation:

\[ \text{MgO} + \text{KH}_2\text{PO}_4 + 5\text{H}_2\text{O} \rightarrow \text{MgKPO}_4 \cdot 6\text{H}_2\text{O} \text{ (K-struvite)} \]

This reaction is fast, exothermic and its mechanism has been described as a multi-step process (Viani et al., 2018). MKPCs are receiving increasing interest because of their excellent properties, namely high early age and long-term strengths, resistance to sulphate attack, rapid setting, near-neutral pH, low shrinkage (Xu et al, 2017). However, there are also some drawbacks, mainly related to the fast kinetics and expensive cost of the starting materials, since MgO needs to be calcinated at high temperature (at least 1500°C). The introduction of FA would be economically beneficial both by reducing the amount of MgO needed and providing a destination for a waste residue which otherwise would require important management costs.

In this work, the incorporation of washed MSWI-FA into MKPC is studied, paying major attention on how and in what extent MSWI-FA participates in the cement reaction. Indeed, an approach similar to the one adopted by Xu et al is employed, where the design strategy takes into account the reactivity of MSWI-FA. In particular, one formulation treats MSWI-FA as fully inert, replacing
both magnesia and KDP, while in another one MSWI-FA is considered as fully reactive, thus replacing magnesia only. The obtained cement pastes are thoroughly characterized by employing spectroscopic (SSNMR, Zn K-edge XANES), X-ray diffraction, SEM-EDS and isocalorimetry techniques.

References