

MUNICIPAL SOLID WASTE INCINERATION FLY ASH AS SUPPLEMENTARY CEMENTITIOUS MATERIAL

Martin KEPPERT

Department of Materials Engineering and Chemistry, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, Prague, Czech Republic, martin.keppert@fsv.cvut.cz

Zbyšek PAVLÍK,

Department of Materials Engineering and Chemistry, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, Prague, Czech Republic, pavlikz@fsv.cvut.cz

Milena PAVLÍKOVÁ,

Department of Materials Engineering and Chemistry, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, Prague, Czech Republic, milena.pavlikova@fsv.cvut.cz

Jan FOŘT,

Department of Materials Engineering and Chemistry, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, Prague, Czech Republic, jan.fort.1@fsv.cvut.cz

Anton TRNÍK,

Department of Materials Engineering and Chemistry, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, Prague, Czech Republic, anton.trnik@fsv.cvut.cz

Jaromír ŽUMÁR,

Department of Materials Engineering and Chemistry, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, Prague, Czech Republic, jaromir.zumar@fsv.cvut.cz

Robert ČERNÝ

Department of Materials Engineering and Chemistry, Faculty of Civil Engineering, Czech Technical University in Prague, Thákurova 7, Prague, Czech Republic, cernyr@fsv.cvut.cz

Summary

Municipal solid waste incineration (MSWI) generates annually at least 25 Mt of solid residues worldwide. Fly ash represents a smaller part of this amount but its chemical composition necessitates application of a treatment technique in order to prevent an environmental damage before its disposal. The most popular treatment method is cement solidification. On the other hand MSWI fly ash has similar properties as coal fly ash and thus it could be utilize as Supplementary Cementitious Material (SCM). Unfortunately the direct application is impossible due to high content of salts in MSWI fly ash and thus a treatment technique is needed. One of possible ways is extraction of fly ash by water or water solutions. The present paper deals with SCM-related properties of MSWI fly ash from a Czech incinerator; the fly ash was treated by water solutions of different pH. The efficiency of fly ash treatment was evaluated by means of measurement of compressive strength and durability of mortars where the ash was used as SCM.

Keywords: MSWI fly ash, SCM, concrete, mechanical properties

1 Introduction

As Supplementary cementitious materials (SCM) is recognized group of natural and anthropogenic (usually by-products of metallurgy or combustion wastes) materials which can take part (either as hydraulic component or pozzolana) in process of hydration of cementitious binder. Admixing of SCMs as partial Portland cement substitution influences properties of fresh (workability) as well as hardened concrete (durability characteristics) [1]. Production of SCMs is less energy consuming than calcination of Portland cement clinker and thus utilization of a SCM as Portland cement substitution improves total energy need for a building construction and obviously also reduces CO₂ emissions generated during the construction works. Many of SCMs are wastes and thus its utilization instead of natural resources (calcite and coal or other fossil fuel) also contributes to sustainable development. Last but not least SCM utilization can reduce price of concrete. The worldwide most used SCM is siliceous fly ash generated in coal power plants. The composition of Municipal Solid Waste Incineration fly ash is more complex since municipal waste contains higher concentrations of alkaline metals, calcium, sulphur, chlorine and heavy metals than coal. MSWI fly ash also contains POPs, e.g. dioxins. The latter two groups of components are environmentally hazardous. One of numerous ways of immobilization of hazardous components of MSWI fly ash is solidification by help of Portland cement. Such solidificate is nowadays disposed of to a landfill but a properly treated MSWI fly ash could be reused as SCM in mixture with Portland cement and applied as binder in building industry. Treatment of MSWI fly ash intended to be used as SCM must ensure particularly reduction of chlorides content since its negative effect on material's setting time.

2 Experimental

The study was dealing with a mix fly ash generated in a MSW incinerator equipped by electrostatic precipitator (ESP), catalytic filter and wet scrubbing of flue gas. The collected fly ash (FA) was subjected to water washing (L/S = 10; 20 min of agitation); solid residuum was filtered out, dried and particles retained on 125 µm sieve were removed (ash W F). The ashes PH 1 F and PH 3 F were washed by help of acid solutions (diluted HCl) of respective pH; the particles retained on 125 µm sieve were removed. The chemical composition of ashes was checked by XRF (Thermo, ARL 9400 XP). The particle size distribution was determined by laser diffraction analyser (Fritsch, Analysette 22 MicroTec plus) in ethanol in order to prevent possible hydration processes. The untreated and washed ashes were applied as partial substitution of ordinary Portland cement (OPC; CEM I 42.5 R) (Tab. 1). The specimens of mortars (160 x 40 x 40 mm prisms) were stored at 100% RH for 28 days and then its bending and compressive strength was measured (ČSN EN 196-1). The resistance of mortars to freezing/thawing action was tested by means of temperature cycling between -20 and 20 °C and subsequent compressive strength determination (ČSN 73 1322).

Tab. 1 Composition of mortars

	OPC	Fly ash	Sand	w/b
	kg/m ³			
Control	460	-	1380	0.52
10%	414	46	1380	0.52
20%	368	92	1380	0.52
30%	322	138	1380	0.52

3 Results and discussion

Chemical composition of ashes is presented in Tab. 2. All washing solutions acted in a similar way – the main difference between FA and washed ashes is decrease of chlorides and alkali metals which indicates presence of NaCl and KCl. The reduction of chlorides content is beneficial for setting time of cementitious materials. The dissolution of soluble chlorides caused relative increase of content of insoluble salts – silicates and sulphates – as well as heavy metals. The influence of pH of washing solution on content of heavy metals in solid residuum was not observed; the approximate heavy metals contents in W F, PH 1 F and PH 3 F were found to be generally higher than in FA. It is a positive finding since heavy metals did not dissolve in the washing solution but remained in the ash. Since the washed ashes were intended to be used as SCM, the efficient immobilization of the present heavy metals was subsequently ensured by cementitious environment itself [2]. The high sulphate content in washed ashes represents long term durability risk. The washing caused refinement of ash particles (Fig. 1) due to dissolution of chlorides which served as a glue of larger particles agglomerates present in FA. However the washed ashes particles were larger than particles of OPC and its size was close to standard requirement on pozzolanic admixture (remains on 45 μm sieve lower than 40 %).

Tab. 2 Chemical composition of treated fly ashes (wt. %)

	FA	W F	PH 1 F	PH 3 F
SiO ₂	15.6	19.1	19.4	19.2
Al ₂ O ₃	9.2	11.6	11.6	11.7
Fe ₂ O ₃	2.6	3.0	3.3	3.0
CaO	23.9	29.9	28.6	30.1
MgO	1.8	2.5	2.3	2.5
Na ₂ O	9.4	2.9	3.0	2.6
K ₂ O	6.6	2.7	2.8	2.7
Cl	11.2	2.8	3.3	2.8
SO ₃	11.5	14.1	15.8	13.9
P ₂ O ₅	1.3	1.7	1.8	1.8

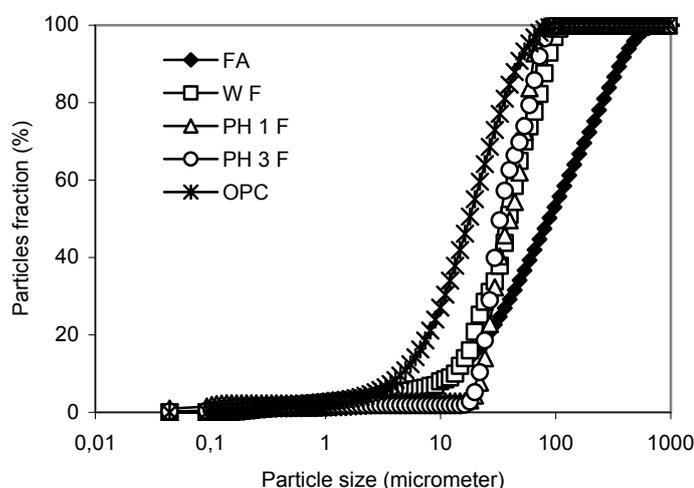


Fig. 1 Particle size analysis of ashes and OPC

The compressive strength of prepared mortars (Tab. 1) was influenced by admixing of washed ashes (Fig. 2). When the untreated ash FA was used as 20 or 30 % cement substitution the compressive strength decreased from 40 MPa to 26 MPa. The washing of fly ash generally improved the strength. The best performance featured water washed ash W F but only its dosing as 10% substitution caused certain improvement of strength. Nevertheless the main technological benefit of utilization of SCM in concrete lies in improvement of its durability; ash W F improved significantly the resistance of mortar to freezing cycles compared to control sample; the strength of mortar containing 30 % cement substitution by W F after 100 freezing cycles was 35 MPa, i.e. it was not negatively affected by freezing action.

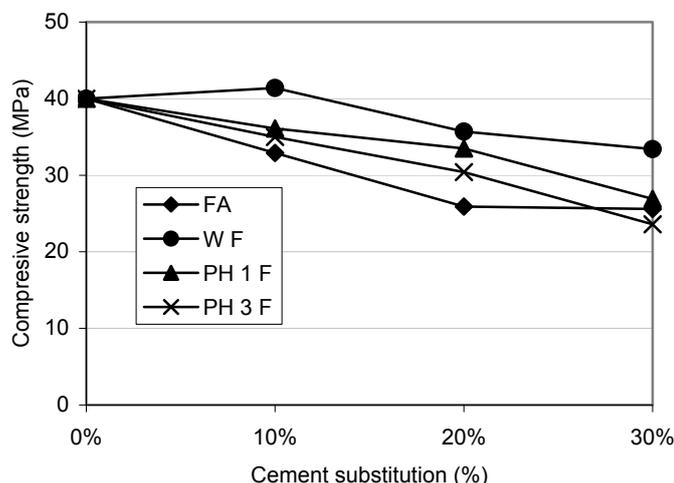


Fig. 2 Compressive strength of mortars containing treated ashes as SCM

4 Conclusions

Influence of washing solution's pH on performance of MSWI fly ash as SCM was tested. The best ability to substitute OPC showed fly ash washed by pure water. The compressive strength of mortar with this ash as SCM was reduced just moderately but its resistance to freezing action was improved. The washing reduced the chloride content in ash while the heavy metals were preserved in solid phase.

Acknowledgement

This research has been supported by the Czech Science Foundation, project No. P104/11/0438.

References

- [1] VEJMELOVÁ, E., PAVLÍKOVÁ, M., KEPPEKT, M., KERŠNER, Z., ROVNANÍKOVÁ, P., ONDRÁČEK, M., SEDLMAJER, M., ČERNÝ, R. *High performance concrete with Czech metakaolin: Experimental analysis of strength, toughness and durability characteristics*. Construction and Building Materials 24 (2010), 1404–1411.
- [2] POHOŘELÝ, M., ŠYC, M., TOŠNAROVÁ, M., ZYCHOVÁ, M., KEPPEKT, M., PUNČOCHÁŘ, M. *Immobilization of heavy metals in MSWI ashes*. Paliva 2 (2010), 113–118.