

The application of MSWI bottom ash fines in high performance concrete

P. Tang, Q.L. Yu, R. Yu, H.J.H. Brouwers

Department of Built Environment, Eindhoven University of Technology,
P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Abstract

In this study, the application of municipal solid waste incineration (MSWI) bottom ash fines (0-2 mm) as aggregate in high performance concrete is experimentally evaluated. The characteristics of bottom ash fines (BA) and sand are measured and compared. The bottom ash fines are used as sand replacement in the proportion of 10%, 20% and 30% by mass of sand; the properties of concrete are investigated. The influential factors of MSWI bottom ash fines on concrete properties are analyzed, and the further research orientation is addressed.

Keywords: MSWI bottom ash fines; sand replacement; porosity; strength; influential factors.

Introduction

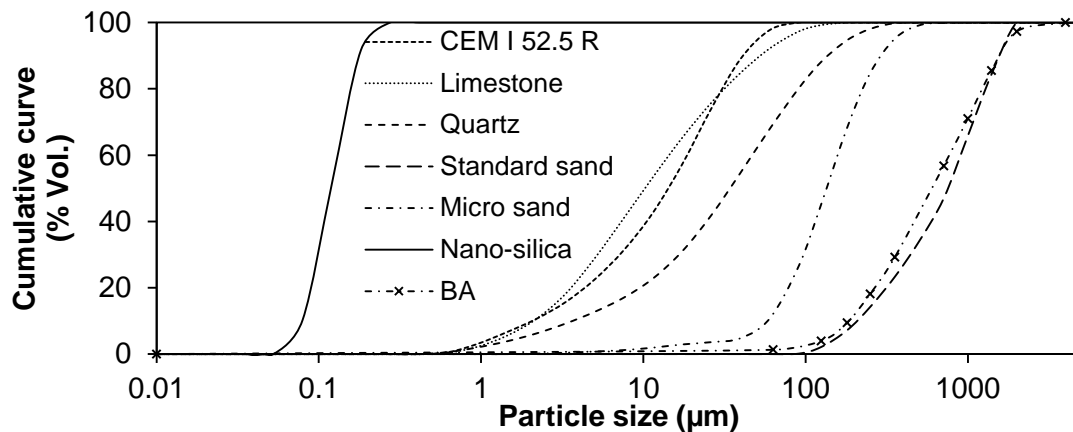
The MSWI bottom ash is the main by-product of the waste-to-energy plant which has the potential to be used as building materials /1/, /2/. The application of MSWI bottom ash in building field can reduce the space for landfilling, and reduce the CO₂ footprint during the production process of building materials. Research studies show the possibility of MSWI bottom ash to be used as aggregates in concrete /3/, /4/. In this study, the MSWI bottom ash fines are used as sand replacement in high performance concrete.

Materials and methods

In this study, the high performance concrete mix is designed applying a methodology based on the modified Andreasen and Andersen model /5/. The materials used for the concrete mixture are listed in Table 1. The particle size distributions (PSDs) of the ingredients are shown in Fig. 1. The bottom ash fines are considered to be used as sand replacement in this designed concrete because of their similar PSDs and specific densities. Compared with the sand used, the bottom ash fines contain higher amount of fineness content (1.29% by mass) and with a loss on ignition of 3.87% by mass.

Table 1. Materials for concrete mixing

Material	Type
Cement	CEM I 52.5 R
Filler	Limestone powder
Fine sand	Micro-sand
Coarse sand	Sand 0-2 mm
Bottom ash fines	0-2 mm
Silica fume	Nano-silica slurry
Superplasticizer	Polycarboxylate ether

**Fig. 1:** The particle size distribution of ingredients for concrete mixing

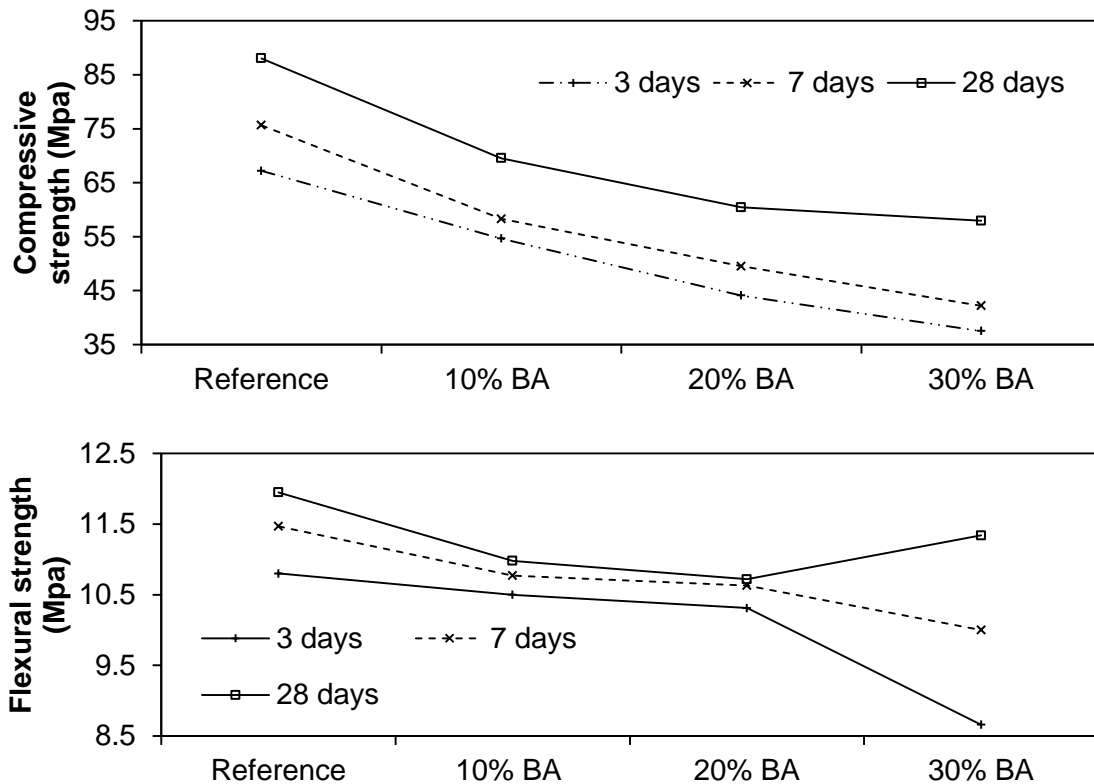
The MSWI bottom ash fines are used in concrete with the replacement ratio of 10%, 20% and 30% by mass of sand. The workability and porosity of the designed concrete are measured, and the compressive and flexural strength of concrete after 3, 7 and 28 days curing are tested. The particle characteristics of bottom ash fines and sand are observed using the optical microscope and Scanning Electron Microscope (SEM), and the cement hydration of the concrete is investigated by an isothermal calorimeter.

Results and discussion

It is shown in Table 2 that the workability of the concrete decreases gradually and the concrete porosity increases linearly with the increase of the bottom ash fines. The compressive and flexural strength of concrete decrease with the increase of the bottom ash fines at the same curing age, especially after 3 and 7 days (Fig. 2). The compressive strength is more influenced than the flexural strength when the bottom ash fines are used.

Table 2. The workability and porosity of concrete

Concrete	Flowability (mm)	Porosity (% Vol.)
Reference	21.25	13.32
10% BA	17.25	15.08
20% BA	14	16.55
30% BA	13.25	18.34

**Fig. 2:** The compressive and flexural strength of concrete

The effects of the MSWI bottom ash fines on the properties of concrete can be explained as follows. Firstly, the bottom ash fines have more fine particles than the sand, indicating more water is needed in order to cover the particle surface; and the bottom ash fines have angular particle shape instead of roundish particles as sand, which would increase the friction between particles, therefore reduce the workability of concrete; also the bottom ash particle surface is rough and covered by dust which would absorb more water. All these factors contribute to the decrease of the concrete workability when bottom ash fines are used.

Secondly, the calorimetric measurement shows that the cement hydration is retarded when the bottom ash fines are used, and the maximum rate of cement hydration is decreased when increasing the bottom ash fines. The more bottom ash fines are applied in concrete, the longer the retardation of cement hydration is resulted (Fig. 3).

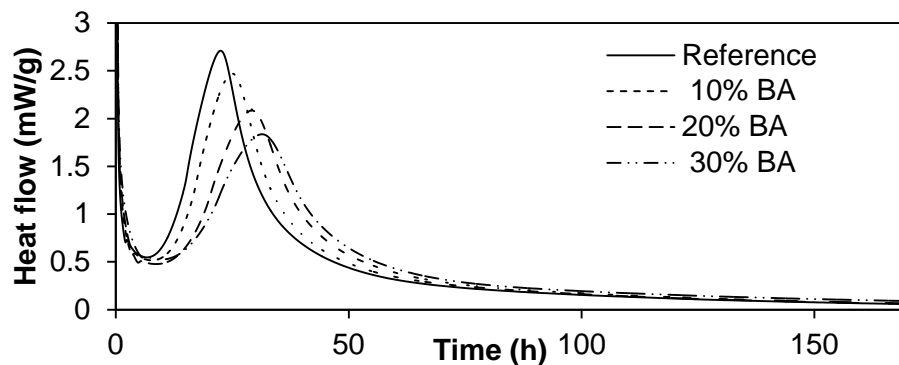


Fig. 3: The rate of cement hydration

Thirdly, it is found that there is a small certain amount of metallic aluminum in bottom ash which would react with alkalis and generate gas when the bottom ash fines are used in concrete. The gas connects the air pores together when finding its way out, and then cracks happen. These cracks cause the increase of the porosity of concrete and then the decrease of the concrete strength.

Conclusion

This study shows that the MSWI bottom ash fines have significant effect on concrete properties when used as sand replacement. In order to use it as building material substitute to reduce the consumption of natural material, and to decrease the amount of solid waste for landfilling, the bottom ash needs to be treated to upgrade its quality, and to remove or find appropriate way to use the metallic aluminum.

Bibliographical references

- /1/ J.R. Pan, C. Huang, J.-J. Kuo, S.-H. Lin: "Recycling MSWI bottom and fly ash as raw materials for Portland cement", *Waste Management (New York, N.Y.)*. 28 (2008) 1113–8
- /2/ O. Ginés, J.M. Chimenos, a Vizcarro, J. Formosa, J.R. Rosell: "Combined use of MSWI bottom ash and fly ash as aggregate in concrete formulation environmental and mechanical considerations" *Journal of Hazardous Materials*. 169 (2009) 643–50
- /3/ R. del Valle-Zermeño, J. Formosa, J.M. Chimenos, M. Martínez, a I. Fernández: Aggregate material formulated with MSWI bottom ash and APC fly ash for use as secondary building material, *Waste Management (New York, N.Y.)*. 33 (2013) 621–7
- /4/ U. Müller, K. Rübner: "The microstructure of concrete made with municipal waste incinerator bottom ash as an aggregate component", *Cement and Concrete Research*. 36 (2006) 1434–1443
- /5/ H.J.H. Brouwers, H.J. Radix: "Self-Compacting Concrete: Theoretical and experimental study" *Cement and Concrete Research*. 35 (2005) 2116–2136