INVESTIGATION ON THE POTENTIAL APPLICATION OF MSWI BOTTOM ASH AS CEMENT SUBSTITUTES

Yubo SUN[1], Boyu CHEN[1], Shizhe ZHANG[1], Kees BLOM[2], Mladena LUKOVIĆ[3], Guang YE[1]

[1] Microlab, Section Materials and Environment, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, 2628 CN Delft, The Netherlands
[2] Gemeente Rotterdam, Ingenieursbureau, the Netherlands
[3] Concrete Structures, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, 2628 CN Delft, The Netherlands

y.sun-4@student.tudelft.nl, b.chen-4@tudelft.nl, shizhe.zhang@tudelft.nl, g.ye@tudelft.nl

Introduction

It has been reported[1] that the economic growth and urbanisation is expected to double the volume of municipal solid waste (MSW) from today's 1.3 billion tons per year by 2025, challenging environmental and public health management worldwide. In recent years, however, most of the MSW incineration (MSWI) bottom ash (BA) are landfilled, and mature technology of BA recovery and utilisation is still scarce. Previous studies have proved the feasibility of using MSWI BA as construction materials, either as aggregate[2] or binder[3] in concrete. Meanwhile, several significant drawbacks have been reported such as leaching property[4], low reactivity[5] and metallic aluminium-induced expansion[6]. However, investigations including both pre-treatment and hydration process of BA is still limited. In this study, a comprehensive pre-treatment method was proposed and performed on the as-received BA. The BA sample with proper treatment was blended into cement paste and the effectiveness of pre-treatment was evaluated by measuring the hydration heat and the compressive strength of hardened cement pastes.

Materials and methods

The MSWI BA used in this study with a particle size of 0-2 mm was provided by Heros BV, a Dutch Waste-to-Energy plant. Proper pre-treatment was performed on BA before they could be used as cement replacement. The metallic aluminium content in BA was removed by mechanical treatment, which is a combination of grinding and sieving, so that the aluminium could be ground into small metal plates during a low-speed grinding process[7] and sieved out easily with a 63 µm sieve (treated BA particles below the sieve are labelled as MBA). Subsequent to the mechanical treatment, a thermal treatment was conducted by heating MBA in a ventilated furnace for 2 hours

at 1000°C under oxygen atmosphere followed by slow cooling to room temperature and the BA obtained is named as MTBA.

The metallic aluminium content of BA samples was determined by a dissolution test[8] with alkaline solution, so that the aluminium content could be estimated by the volume of the hydrogen gas collected in the test.

Treated BA samples were blended into cement paste, and the details of mixture design are given in Table 1, water to cement ratio of each kind of binders was kept to 0.5. CEM I 42.5N cement and M300 (pure quartz sand without reactivity) were selected as reference materials. Cement pastes were prepared according to EN 196-1, and cast into cubes with a dimension of 20*20*20 mm. The cement cubes were first sealed and cured in room ambient for 24 hours, then after demoulding they were transferred into a curing room (room temperature, 95% relative humidity) until 7 and 28 days.

Table 1: Mixture design of cement pastes

(Unit: g)	CEM I 42.5N	MBA	MTBA	M300
Ref. cement	200			
10% MBA	180	20		
10% MTBA	180		20	
10% M300	180			20

MBA: Mechanically treated BA
MTBA: Mechanically and thermally treated BA
M300: Pure quartz sand without reactivity, reference material

The hydration heat was measured by isothermal calorimeter to evaluate the effectiveness of pre-treatment together with compressive strength tests of hardened pastes at the age of 7 and 28 days.

Results and discussion

Metallic aluminium content

The results of dissolution tests showed that the initial metallic aluminium content in raw BA is 0.8%, which dropped significantly after mechanical and thermal treatment (0.13% and 0.06% separately in MBA and MTBA). The results prove the mechanical treatment is rather effective in removing the metallic aluminium. Moreover, the metallic aluminium content in MTBA is further reduced to almost zero. This could be attributed to the high-temperature thermal treatment so that the content of remaining metallic aluminium particles was further declined through accelerated oxidation process.

Hydration heat

The development of heat flow and cumulative heat with different kinds of pastes during the hydration process are given in Figure 1.

In general, a peak value of heat flow appeared in each curve at around 20 hours. The maximum normalised heat flow of MBA and M300 decreased 12.18% and 9.29% respectively. Meanwhile, a remarkable delay of the peak value is observed in 10% MBA group and the maximum heat release rate is even smaller than 10% M300, which proved that the addition of MBA negatively affected the hydration process and the early-stage hydration reaction was retarded by MBA. As for cumulative heat development, cement blended with 10% MBA also exhibited rather slow early-stage heat development. However, a reversal trend occurred at around 40 hours and after that, the total amount of heat release of 10% MBA is higher than that of 10% M300. It could be inferred that thermal treatment mainly activated the BA and accelerated the early-stage heat development.

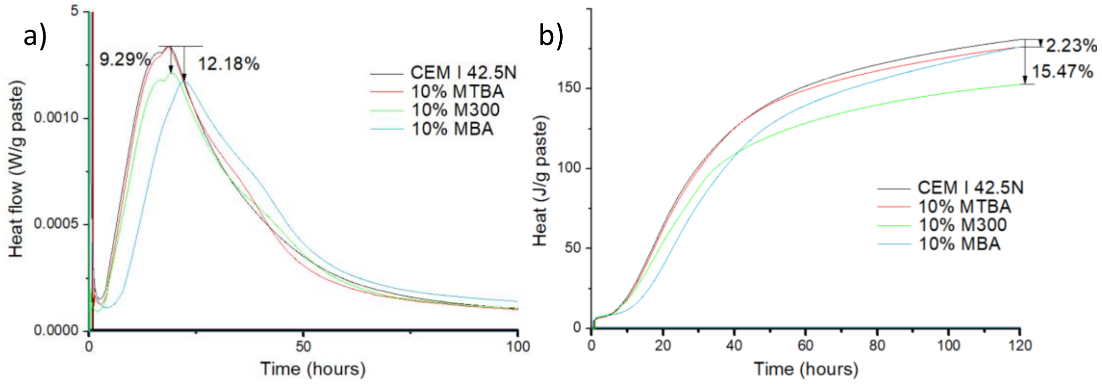

Figure 1: Heat development of cement pastes, with a) heat flow normalised to mass of paste, and b) cumulative heat release normalised to mass of paste

Compressive strength of hardened paste

The results of 7-day and 28-day compressive strength test with different kind of cement paste are shown in Figure 2.

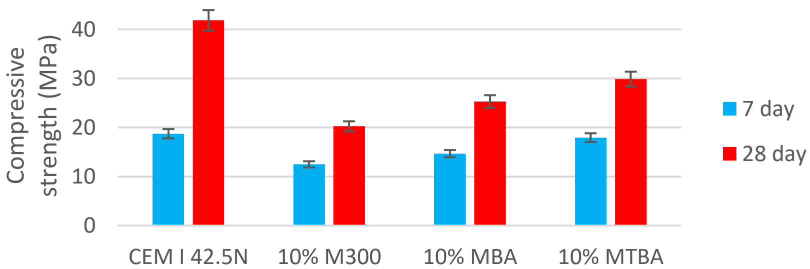

Figure 2: Compressive strength of cement pastes

A decrease of compressive strength is observed in the mixture with treated BA. On the other hand, comparing the performance between MBA and MTBA, 10% MTBA exhibited higher 7-day and 28-day compressive strength, which could be attributed to the thermal treatment which enhances the reactivity of MTBA. The result indicates that both MBA and MTBA would contribute more to the hydration process and strength development than pure sand. This is important since it serves as a solid evidence that BA after proper treatments could be used as supplementary cementitious material rather than inert filler.

Conclusions

- The mechanical treatment is effective in removing the metallic aluminium content in BA, and the remaining metallic aluminium could be further removed by oxidation through thermal treatment.
- According to the results of compressive strength and hydration heat, both MBA and MTBA works better than pure sand, which proves the contribution of BA to the hydration process. The difference between MBA and MTBA indicates that thermal treatment could increase the reactivity of BA particles.
- The result of this study also indicates that MBA is already good enough to be used as filler substitute material in concrete since the 7-day and 28-day compressive strength of mortar strength with 10% MBA is higher than that with same amount of M300.

References

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