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**Improving durability of reinforced concrete structures by recycling wet-ground MSWI
bottom ash**

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This paper is dedicated to Jürgen Mietz in the occasion of his 60th birthday

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Municipal solid waste incineration (MSWI) generates high amounts of bottom ash that, after grinding, could be used as mineral addition for concrete. Wet grinding of the bottom ash can prevent the risk of deleterious expansion due to hydrogen evolution, associated to the presence of metallic aluminium. The pozzolanic behaviour of the bottom ash may improve concrete resistance to the penetration of aggressive species. Advantages of recycling wet-ground MSWI bottom ashes may even be higher when self-compacting concrete (SCC) is used, which requires large quantity of fine powders (usually more than 500 kg/m^3) to prevent segregation of the fresh mix.

This paper describes the results of a research aimed at investigating the use of wet-ground MSWI bottom ashes as mineral additions for the production of self-compacting concrete. Several types of mineral additions (MSWI bottom ash, coal fly ash and ground limestone) were used in replacement of 15, 30 and 45% of Portland cement. The results showed that the MSWI ash, added to the mix as a fine slurry obtained by wet-grinding, led to the production of SCC concrete with compressive strength and resistance to chloride and carbonation similar, or even better, than those of concrete with same amount of coal fly ash.

Keywords: MSWI bottom ash, Self-compacting concrete, Chloride, Carbonation, Corrosion?.

1 Introduction

Waste materials with pozzolanic or hydraulic properties are nowadays considered as highly beneficial for the durability of reinforced concrete (RC) structures. Indeed, used in partial substitution of the Portland cement clinker and after sufficient curing, these materials can lead to a favorable refinement of the pore structure of the hardened cement paste, which

remarkably improves the resistance of concrete to the penetration of aggressive ions [1-6]. For instance, addition of coal fly ash (*C-FA*) or ground granulated blastfurnace slag (*GGBS*) is a common design strategy to delay the penetration of chlorides through the concrete cover and, thus, improve the durability of reinforced concrete structures that suffer chloride-induced corrosion of embedded steel bars [7].

The use of recycled pozzolanic materials may be especially interesting when self-compacting concrete (*SCC*) is used. *SCC* is a recent innovation in the field of concrete technology. Being able to flow under the effect of its own weight, it does not require any compaction even in the case of structures with a complex geometry or congested rebars [8-10]. This concrete is attractive since it gives advantages in terms of both reduction in time of casting and independence of the quality of the concrete from the ability of workmanship, favoring the durability of the reinforced concrete structures. However, to obtain a flowable concrete, prevent the blockage of coarse aggregate between the reinforcing bars and, in the mean time, avoid the segregation of the mixture, high dosages of both superplasticizer and fines (i.e. materials with a particles size below 100 μm) are required [11-12]. Furthermore, in order to prevent risks of cracking associated to the heat of hydration or drying shrinkage, mineral additions are normally used as fine materials to replace part of the cement. These may either be inert (such as ground limestone) or have hydraulic or pozzolanic properties. While the former is expected to have only marginal influence on the long-term properties of the hardened concrete, the latter may contribute to the improvement of the performances of hardened concrete.

Besides traditional pozzolanic additions (like *GGBS* or *C-FA*), many other wastes have been proposed as supplementary cementitious materials with pozzolanic or hydraulic properties [13-17]. In a previous study [18] it was shown that also bottom ash produced by municipal solid waste incinerator (*MSWI-BA*) may have pozzolanic properties in concrete, provided that

it is wet-ground in order to obtain a fine slurry. *MSWI-BA*, in fact, may only be used in concrete if deleterious effects associated to the presence of aluminium [18-27] can be prevented, especially the development of bubbles in the fresh concrete due to the hydrogen evolution associated to the cathodic reaction of corrosion of aluminium particles. When *MSWI* bottom ash is wet ground, it can be used as a slurry which allows, on the one hand, to increase the fineness and, on the other hand, due to its alkaline pH to corrode aluminium and let hydrogen evolution to take place. When fine aluminium particles in the slurry are depleted, also hydrogen evolution is exhausted and the slurry can be safely used for concreting. Considering the large amount of fines required for the production of self-compacting concrete, the recycling of *MSWI* bottom ash in the production of SCC could be a smart solution to improve the durability of reinforced concrete structures and, in the mean time, improve sustainability of the construction field by recycling a widespread and abundant waste.

This paper discusses the results of a research aimed at studying the use of different amounts of wet-ground *MSWI* bottom ash, and for comparison of other mineral additions, for the production of self-compacting concrete. Properties of SCC in the fresh and hardened state were investigated, focusing on those related to the protection of the embedded steel against carbonation- and chloride-induced corrosion.

2 Materials and methods

2.1 Characterization of *MSWI-BA*

Tests were carried out using bottom ashes collected from a municipal solid waste incinerator (*MSWI-BA*), whose chemical composition is shown in Table 1. The ash was air-dried in the lab and ferrous metals were removed with a magnet; unburned materials visible at the naked eye were also removed. Then the ash was crushed and (dry) ground in order to obtain two fractions: one with maximum size (d_{\max}) of 14 mm and average size (d_{50}) of 4 mm (named *D-*

4000) and the other with d_{\max} of 2.36 mm and d_{50} of 0.65 mm (named *D-650*). A portion of *D-650* was subjected to a treatment aimed at the separation of non-ferrous metals (based on Eddy current), in order to reduce the aluminium content (this sample was named *D-650-T*). The wet-grinding process was applied to both *D-650* and *D-650-T* samples; they were first dry-ground to achieve a d_{50} of about 60 μm and then mixed with water to obtain a slurry with a solid/total mass ratio of 0.44. the slurry was then wet-ground , obtaining particles respectively with d_{\max} of 20 μm (sample *W-3.5*) and d_{50} of 3.5 μm (sample *W-3.5T*).

In order to estimate the amount of hydrogen developed in alkaline environments by the *MSWI-BA* subjected to different types of grinding or treatment, about 5 g of ash (or 10 g of slurry) was diluted in 150 mL of distilled water at 23°C and 10 g of NaOH was added. The volume of hydrogen gas developed by the reaction of aluminium (or possibly also by other non-ferrous metals) was measured using a burette and it was referred to the dry mass of the ash.

Mortars prisms (40x40x160 mm³) were cast with the different samples of ash. Mortar was cast with 308 kg/m³ of limestone Portland cement, 132 kg/m³ of dry ash, 220 kg/m³ of water (including the water of the slurry for wet-ground samples) and 1760 kg/m³ of sand. Hardened specimens were visually observed, in order to verify possible expansion of the mortar during setting, and the compressive strength was measured after 7 days of moist curing, in order to evaluate possible negative influence of hydrogen development during setting.

2.2 Tests on SCC

The *W-3.5* sample of wet-ground MSWI bottom ashes was used to study the effects of the ash on the properties of self-compacting concrete. The *MSWI-BA* slurry was used at least 24 hours after grinding, to allow depletion of aluminium particles and thus ending of hydrogen evolution. For comparison a coal fly ash (*C-FA*, with $d_{\max} = 100 \mu\text{m}$ and $d_{50} = 20 \mu\text{m}$ and the

composition shown in Table 1) and a commercial a ground limestone (*LI*, with $d_{\max} = 100 \mu\text{m}$) were also considered as mineral additions.

A reference self-compacting concrete (named *CEM*) was made by using 100% of limestone portland cement CEM II/A-L 42.5R (according to EN 197-1 standard). Mix proportions were: 500 kg/m^3 of cement, 215 kg/m^3 of water and 1690 kg/m^3 of a crushed limestone aggregate. The water/cement ratio was 0.43. Other nine SCC concretes were made with the same mix proportions, except for the replacement of 15%, 30% or 45% of cement with the three different mineral additions (*MSWI-BA*, *C-FA* and *LI*). The *MSWI-BA* was added in form of slurry and the water in the slurry was considered in the calculation of the mixing water. The water/cement ratio was then 0.51, 0.61 and 0.78 respectively for concrete were 15%, 30% or 45% of cement was replaced (Table 2). An acrylic superplasticizer was used to achieve the required workability.

Rheological properties of fresh concrete were tested by using typical workability tests developed for self compacting concrete, i.e. slump flow test and V-funnel test [12]. Compressive strength of hardened concrete was measured on 100 mm cubes after 1, 7, 28, 90 and 180 days of moist curing at 20°C . Electrical resistivity of the hardening material was monitored by measuring the conductance of $40 \times 40 \times 160 \text{ mm}^3$ prisms immersed in tap water, in order to investigate changes in the microstructure of the cement paste due to hydration. Resistance to chloride penetration was studied on cylinder specimens (with diameter of 100 mm and height of 60 mm), according to the procedure proposed by NT BUILD 443 [28]. After 28 and 90 days of curing the lateral surface and one of the flat surfaces of the specimens were masked with epoxy paste, so that chloride penetration was allowed only from the remaining flat surface. Specimens were then immersed in an aqueous solution with 165 g/L of sodium chloride. After 35 days of immersion, chloride profiles were measured; powders obtained by using a profile grinder were digested in nitric acid and the chloride content was

measured by means of potentiometric titration with silver nitrate. The resistance to the penetration of carbonation was evaluated on concrete cubes with all the faces except one masked with epoxy paste. After 28 days of curing specimens were exposed to a chamber saturated with carbon dioxide at 20°C and with controlled relative humidity of 65%. The penetration of the carbonation depth was measured with the phenolphthalein test on cores, after different times of exposure. The carbonation depth was also measured on specimens exposed outside and sheltered by the rain.

Drying shrinkage was measured on 100x100x500 mm³ prisms cured for 28 days and then exposed to 20°C and 50% R.H. for 2 months.³ Results and discussion

3.1 Prevention of expansion due to hydrogen gas

In order to allow recycling of MSWI bottom ash in concrete, the deleterious expansion of concrete during setting due to the development of hydrogen gas from metallic aluminium present in the MSWI bottom ash should be prevented. In this work, following the approach previously proposed in ref. [18], the use of a wet-grinding process was considered. The wet-grinding process allows to achieve a high level of fineness of the particles and to obtain an alkaline slurry (with pH above 11) in which depletion of aluminium (and thus also the associated gas production due to the cathodic process of hydrogen evolution) may occur before mixing in the concrete. Figure 1 compares the volume of hydrogen per unit mass produced in alkaline environment by the MSWI bottom ash under different conditions of grinding. Particles subjected to dry grinding, leading to d_{50} of both 4 mm (sample *D-4000*) and 0.65 mm (sample *D-650*), developed about 6 mL of gas per gram after about an hour of immersion in a highly alkaline solution. Conversely, the gas developed by the slurry obtained by wet-grinding (sample *W-3.5* with d_{50} of 3.5 μm) was negligible. No effect of the treatment based on eddy current for the removal of non metallic particles was observed; in fact, the treated sample *D-650-T* developed the same amount of hydrogen as the corresponding

untreated sample *D-650*. Similarly, after wet-grinding the treated sample *W-3.5-T* showed the same behaviour of the untreated sample *W-3.5* (Figure 1).

Results of this test were also confirmed by tests on mortar specimens, which showed lower strength when the MSWI bottom ash was used after dry grinding (even when subjected to the eddy current treatment), compared to mortar specimens with addition of wet-ground ashes (Figure 2a). Expansion of mortars made with the dry-ground ash was also confirmed by visual observation of the specimens, as shown in Figure 2b.

Thus, it was confirmed, on the one hand, that gas evolution during setting may seriously damage concrete and, on the other hand, that this effect can be prevented by the wet-grinding process and the consequent use of the MSWI bottom ash in form of fine slurry.

3.2 Characterization of SCC

To study the effects of MSWI bottom ash on the properties of self-compacting concrete, comparison was made between a reference concrete (designated as CEM) where all the fines (500 kg/m^3) were made by cement and concretes where a percentage of 15%, 30% or 45% of cement was replaced by wet-ground MSWI bottom ash (these concretes were named with the percentage of cement replacement followed by MSWI-BA). On the basis of the previous results, the wet-ground MSWI bottom ash without treatment for aluminium removal (sample *W-3.5*) was selected for tests in self-compacting concrete. For further comparison, concrete was also made by replacing 15%, 30% and 45% of cement with coal fly ash (C-FA), representative of a traditional pozzolanic addition, and ground limestone (LI), representative of a typical inert addition.

3.2.1 Rheology

Fines have a direct effect on the workability of the self-compacting concrete, depending both on the type and the amount of the addition. Table 3 shows the results of workability tests [12] and the dosage of superplasticizer in each mixture. The reference concrete (CEM) had a slump flow of 710 mm; the time for reaching a spread diameter of 500 mm (T_{500}) was 3.5 s,

while the time to empty the V-funnel was 7 s. Concretes with replacement of 15%, 30% and 45% of cement with ground limestone (*LI*) and coal fly ash (*C-FA*) reached a slightly higher slump flow (700-775 mm) with a dosage of superplasticizer comparable to that of the reference concrete (1.4-2.2% by mass of cement). Concrete in which the cement was replaced with wet-ground MSWI bottom ash (*MSWI-BA*) reached the same workability levels, but they required much higher amounts of superplasticizer, especially for the mixture with the highest percentage of addition (45% *MSWI-BA*). All the concrete mixes showed a good cohesion. Thus, in spite of the increased request for superplasticizer due to high fineness of the particles, the wet-ground MSWI bottom ash was suitable for the production of a self-compacting rheological behaviour of the fresh concrete.

3.2.2 Mechanical properties

The contribution to the compressive strength of the MSWI bottom ash and other mineral additions is shown in Figure 3. As an example, Figure 3a compares the evolution in time of the compressive strength (two replicate specimens) in the reference concrete and in the specimens with 30% of replacement of cement with the different mineral additions. Figures 3b, 3c and 3d show the effect of the type and percentage of addition after 7, 28 and 180 days of curing respectively (average of two replicate specimens). Replacement of cement with ground limestone led to a decrease in the compressive strength; at any curing time, the higher was the percentage of cement replaced by ground limestone the lower the strength was. For instance, after 28-day curing (Figure 3c) the compressive strength decreased from 64.7 MPa of the reference concrete with 100% cement to 50.1 MPa, 45 MPa and 31.7 MPa respectively for concretes with 15%, 30% and 45% of ground limestone.

Self-compacting concretes with coal fly ash (*C-FA*) showed initially an intermediate behaviour between the reference concrete and concrete with ground limestone (Figure 3b). After only one day of curing they reached strength values similar to those of the concretes with the same amounts of ground limestone (Figure 3a), thus lower than that of the reference

concrete. Nevertheless, the compressive strength of *C-FA* concrete increased in time and approached or exceeded the strength level of the reference concrete (Figure 3*c-d*). This shows that a pozzolanic addition, as the coal fly ash, besides providing the amount of fines necessary to achieve a self-compacting behaviour in the fresh concrete, may actively contribute to improve the properties of the hardened material. Already after 28 days of curing the compressive strength of concrete with a content of fly ash of 15 and 30% approached that of the reference concrete (Figure 3*c*); a lower strength was only observed in the concrete with 45% of fly ash. After 6 months of curing the concrete with 30% of fly ash had a strength of 78 MPa, higher than that of the reference concrete. Nevertheless, the low strength values obtained after 7 days of curing showed how pozzolanic materials suffer from a short curing and thus advantages of pozzolans may be hindered by bad curing.

Self-compacting concretes with the wet-ground MSWI bottom ash (*MSWI-BA*) had compressive strengths similar to those measured on concrete with coal fly ash. In some cases, even higher values were reached; for instance, concrete with 30% *MSWI-BA* after six months of curing had a strength of 87 MPa, significantly higher than that measured on the other materials (Figure 3*d*). This is probably due also to the high fineness of this addition (d_{50} of *MSWI-BA* is 3.5 μm compared to 20 μm of *C-FA*).

3.2.3 Drying shrinkage

Figure 4 compares the drying shrinkage of the self-compacting concretes. As expected, the replacement of 30% of cement with the different types of mineral additions, including the MSWI bottom ash, reduced the drying shrinkage (Figure 4*a*). Variable and uncertain results were obtained in the tests where only 15% of the cement was replaced (Figure 4*b*).

3.3 Corrosion protection of steel bars

The pozzolanic behaviour of the MSWI bottom ash may play an important role in improving the durability performance of self-compacting concrete, especially in relation to the corrosion protection of embedded steel bars [7]. This effect will be analyzed, firstly, by the pore

refinement induced by the mineral additions, through the investigation of the evolution in time of the electrical resistivity of concrete specimens cured under-water. Then, the effects on the resistance to carbonation and the penetration of chloride ions will be investigated by considering the parameters normally used for the performance-based design of reinforced concrete structures, i.e. the carbonation coefficient K and the apparent diffusion coefficient D_{app} [29-32].

3.3.1 Pore refinement

To evaluate the microstructural changes of the different concretes as a function of curing, electrical resistivity measurements were carried out on water-saturated specimens (Figure 5). Under saturated condition, changes in time in resistivity are primarily related to changes in the capillary porosity due to hydration of cement and possible pozzolanic reactions. Figure 5a shows the evolution in time of the resistivity in the reference concrete and in concretes with 30% of cement replacement by mineral additions. It can be observed that the pozzolanic behaviour of MSWI bottom ash led to a remarkable increase in time of resistivity, which reached values even slightly higher than that observed for the specimen with 30% coal fly ash. Such an increase is an indirect measurement of the beneficial refinement of the capillary pores produced by the pozzolanic reaction. In fact, refinement of the pore structure decreases the mobility of ions in the water-saturated pores and thus increases the electrical resistivity.

Concrete with ground limestone (LI) showed resistivity values slightly lower than those measured on the reference concrete ($40 \Omega \cdot m$). Ground limestone, being an inert addition, does not contribute to hydration reactions; the slight decrease in resistivity was a consequence of the “dilution” of the cement due to its partial replacement with this addition [33].

Figure 5b shows the effect of the type of addition and the percentage of cement replacement on the electrical resistivity measured after 28 days of curing. Concretes with wet ground MSWI bottom ash showed a higher resistivity compared to concretes with coal fly ash at any percentage of cement replacement; the highest value of resistivity after 28 days ($280 \Omega \cdot m$)

was obtained on the concrete with 45% *MSWI-BA*. This result may be a consequence of improved hydraulic properties of *MSWI-BA*, which have a higher CaO content compared to *C-FA* (Table 1) and thus may hydrate in the presence of less calcium hydroxide, or may also be a consequence of the higher fineness of this addition.

3.3.2 Resistance to carbonation

As far as resistance to carbonation is concerned, it should be considered that pozzolanic additions, besides bringing about a positive refinement of the pore structure, may reduce the amount of portlandite in the hydration products (due to the pozzolanic reaction) and thus reduce the concrete alkalinity. To compare the materials studied with regard to the protection provided to the embedded steel, their resistance to carbonation was studied by means of both accelerated tests (Figure 6) and natural outdoor exposure tests (Figure 7). Figure 6a shows, as an example, the depth of accelerated carbonation as a function of time in the specimens with 30% of cement replacement. The reference self-compacting concrete (*CEM*) showed a carbonation depth of about 14 mm after 1 year of exposure. The carbonation depth increased when 30% of the cement was replaced by the inert addition of ground limestone (*30% LI*), reaching 42 mm after 1 year of exposure. Concrete with 30% coal fly ash (*30% C-FA*) showed an intermediate resistance to carbonation between *CEM* and *30% LI* (carbonation depth was 22 mm after 1 year). Concretes made with wet ground *MWSI* bottom ash (*30% MSWI-BA*) showed a carbonation depth slightly higher than that of *30% C-FA* (29 mm). Results of exposure to an outdoor environment sheltered by rain, shown in Figure 7a, confirm the same ranking of the resistance to carbonation of the tested self-compacting concretes, although obviously lower carbonation depth were measured.

Experimental data in Figures 6a and 7a were interpolated with the typical parabolic formula used to correlate the carbonation depth (x) with time (t): $x = K \cdot \sqrt{t}$, in order to determine the carbonation coefficient K , measured in $\text{mm} \cdot \text{year}^{-0.5}$. Figures 6b and 7b plot the coefficient K derived from respectively the accelerated tests (K_{acc}) and outdoor tests (K_{outdoor}), as a function

of the type and percentage of addition. It can be observed that the lowest values of K_{acc} and $K_{outdoor}$ were measured in the reference concrete, while the worst behaviour was shown by concrete with addition of limestone (in the concrete with 45% *LI* the values of K_{acc} and $K_{outdoor}$ were about 5 times higher than the corresponding values measured in the reference concrete). Concrete with *MSWI-BA*, similarly as concrete with *C-FA*, showed a decrease in the resistance to carbonation as the percentage of cement replacement increased, both in accelerated tests and in natural exposure tests. Nevertheless, they showed a better behaviour than concrete with ground limestone and K_{acc} and $K_{outdoor}$ reached values 2-3 times higher than the reference concrete even when 45% of cement was replaced. These results show that the use of wet ground MSWI bottom ash as fines for SCC may improve the resistance to carbonation compared to the use of inert additions like ground limestone.

3.3.3 Resistance to chloride penetration

Due to the previously mentioned pore refinement, mineral additions with pozzolanic behaviour are known to induce a clear beneficial effect with regard to the resistance to chloride penetration of concrete. In order to assess the role of wet-ground MSWI bottom ash, accelerated chloride penetration tests were carried out. Figure 8a shows, as an example, the chloride profiles measured on specimens of concretes with 30% cement replacement, which were immersed in a solution with 165 g/L of sodium chloride after 28 days of wet curing. The same type of test was also carried out on specimens cured for 90 days

All the experimental chloride profiles were fitted with the following relationship:

$$C_x = C_s \left(1 - \operatorname{erf} \frac{x}{2\sqrt{D_{app} \cdot t}} \right)$$

which derives from Fick's second law of diffusion [34], in order to evaluate an apparent diffusion coefficient D_{app} [7] which may be used to compare the resistance to chloride penetration of different concretes.

The apparent diffusion coefficients obtained by fitting experimental data of specimens cured for 28 days ($D_{app,28d}$) are shown in Figure 8b, while values obtained from specimens cured for 90 days ($D_{app,90d}$) are shown in Figure 8c.

Opposite trends are shown by the concretes with ground limestone and those with coal fly ash and MSWI bottom ash. In specimens cured 28 days, for instance, concretes with ground limestone showed a remarkable increase in the diffusion coefficient as the percentage of replaced cement increased. D_{app} increased from $16 \cdot 10^{-12}$ m²/s in the reference concrete to $28 \cdot 10^{-12}$ and $50 \cdot 10^{-12}$ m²/s in the concrete respectively with 15% and 30% *LI* (Figure 8b). Also, concretes with addition of coal fly ash and wet ground MSWI bottom ash showed low values of the apparent chloride diffusion coefficient. Concretes with 30% *C-FA* and 30% *MSWI-BA*, for instance, showed values of diffusion coefficient lower by one order of magnitude compared to those measured in specimens with 30% ground limestone (Figure 8b). This clearly shows the advantage of using pozzolanic additions, like both traditional coal fly ash and MSWI bottom ash, instead of ground limestone with regard to the long term durability of self-compacting concrete. Provided that a proper concrete cover thickness and a good curing of concrete are guaranteed, the use of self-compacting concrete with this type of fine additions can be a good choice in the design for durability of reinforced concrete structures exposed to chloride bearing environments. In fact, the impervious cement matrix produced by the hydration of the mixture of clinker and the pozzolanic materials can guarantee a long-term protection from chloride penetration.

Considering all the results presented in this paper, a good performance of self-compacting concretes made with wet ground municipal solid waste incinerator bottom ash can be observed. In fact, it was confirmed that the wet grinding process can prevent any risk of expansion due to hydrogen arising from the cathodic process of the corrosion of aluminium

particles in the ground bottom ash even when large amounts of ashes are used. It was furthermore shown that, apart from a higher dosage of superplasticizer, the use of large available quantities of MSWI bottom ash could be advantageous for making durable self-compacting concretes. Before that, possible environmental hazards related to the use of this type of mineral addition in real structures should be evaluated. Even though MSWI bottom ashes have a negligible content of chlorides and heavy metals and these are expected to be bound in the dense cement matrix of a structural concrete, any possible risk of leaching should be evaluated taking into account the exposure condition of the structure, its destination, the effect of degradation or ageing phenomena (e.g. carbonation, cracking), etc. Also possible risks related to the demolition of the structures at the end of their service life should be considered.

4 Conclusions

The type of fine addition used in replacement of cement for the production of self-compacting concrete showed to play a key role with regard to strength and durability-related properties of hardened concrete. Considering the traditional mineral additions, it was observed that coal fly ash, thanks to its well-known pozzolanic behaviour, may lead to a refinement of the pore structure and thus a remarkable reduction in the rate of penetration of chloride ions; conversely, the use of ground limestone significantly increased the rate of chloride penetration during diffusion tests. Concretes with fly ash also showed an improved resistance to carbonation, compared to concretes with ground limestone filler.

Bottom ashes from municipal solid waste incinerators could be used as mineral additions only in the form of a fine slurry obtained by a wet grinding process, which allowed to prevent deleterious expansion of concrete during setting due to corrosion of aluminium particles. No advantages related to previous application of an eddy current treatment for separation of non-ferrous metals were observed.

Wet-ground MSWI bottom ash only required a higher dosage of superplasticizer, compared to coal fly ash and ground limestone, in order to produce a cohesive self-compacting concrete. Hardened self-compacting concrete made with MSWI bottom ash had compressive strength and resistance to chloride and carbonation that were similar, or even better, than those of concretes with the same amounts of coal fly ash. These results show that the great amount of fines required by the production of self-compacting concrete could be derived by recycling MSWI bottom ash, which is a waste produced in large amounts throughout the world and it is normally disposed of in landfills.

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Graphical Abstract

The table of contents (ToC)

Bottom ash produced by municipal solid waste incineration, after wet grinding, is proposed as mineral addition for self-compacting concrete. The alkaline slurry produced by the wet grinding process allow quick corrosion of fine aluminium particles present in the ash, thus preventing the deleterious expansion of concrete during setting due to hydrogen evolution. The pozzolanic properties of this recycled waste improve durability-related properties of concrete.

ToC figure ((Please choose one from your article or one specifically designed.

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