CERIS Civil Engineering Research and Innovation for Sustainability

ECOncrete – Self-Compacting Concrete Incorporating Bottom Ash Resulting from Municipal Solid Waste Incineration

Summary

The purpose of this project was to assess the feasibility of producing self-compacting concrete (SCC) with a very low environmental impact, in particular regarding carbon dioxide (CO2) emissions by replacing part of the cement with municipal solid waste incinerator bottom ash (MIBA).

Municipal solid waste (Figure 1) is produced in large quantities worldwide, with production approaching 1.3 billion tons per year in 2012 and an increase of 2.2 billion tons per year is expected until 2025. This fact represents a significant increase in waste production per capita, from 1.2 to 1.42 kg per person/day. In the incineration of municipal solid waste, bottom ash is the most important by-product, representing 85% to 95% of the waste remaining after combustion (Figure 2).

Figure 1. Slag deposit.

Figure 2. Processed bottom ash deposit.

The SCC specific workability needs, due to the absence of vibration, imply, among other changes, a powdery material volume increase (cement and SCM). It is thus possible to combine the need for a greater powdery material volume with the urgent need to reduce global cement consumption, due to the high CO_2 emissions associated with its production, which, in the short term, may be effected by substituting clinker and /or cement itself by other materials such as MIBA. However, it is considered essential to demonstrate its applicability in higher quantities (both in binary and ternary mixtures), namely in durability terms.

Thus, the main objective of this work was to evaluate the SCC properties, both in the fresh state (self-compactability) and in the hardened state (mechanical and durability behavior), in binary and ternary mixtures of cement, FA and MIBA, with cement replacement percentages for the binary mixtures of 30, 40, 50 and 60%, and with four pairs of different values for the ternary mixtures: 10% FA + 20% MIBA, 20% FA + 10% MIBA and 20% FA + 40% MIBA, 40% FA + 20% MIBA.

Although MIBA can be deemed pozzolanic, it has lower reactivity in comparison with that of FA and thus the strength development over time is affected due to the lower amount of strength-enhancing mineralogical phases. These same factors influenced the durability performance of the mixes, though to a lower extent in some cases (i.e., 28-day water absorption by immersion). Naturally, as a result of the increased porosity and reduced quantity of phases capable of binding ions, chloride ion diffusion and resistivity increased and decreased, respectively, thereby limiting the use of MIBA as SCM in applications that are not subjected to chloride-enriched environments.

Considering the results obtained regarding the production of binary mixtures, the following general conclusions can be presented:

- As for the mechanical performance, the C20 mixture (20% replacement) presents the most favourable overall results of mixes containing MIBA. The rest of the mixtures present considerably higher performance losses, particularly the mixtures C40 and C50 (40% and 50% replacement respectively), which did not present enough compressive strength for a real structural situation;
- Regarding the durability-related performance, SCCs produced with MIBA present a promising behaviour. The C20 mixture stood out as the most advantageous mixture with MIBA, presenting values very similar to those of the RC mixture for most of the studied properties. The C50 mixture, on the other hand, presented the worst behaviour of all the mixtures.

Although the MIBA led to a decline in mechanical properties, evaluating the overall performance of the resulting concrete, as long as the percentage of replacement does not exceed 20%, the MIBA can prove to be promising, since it does not significantly hinder

Project Reference

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Leading Institution

ISEL – Instituto Superior de Engenharia de Lisboa (Portugal)

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the fresh behaviour of the SCC and represents a new value-added solution for bottom ashes from incinerated municipal solid wastes.

Considering the results obtained regarding the production of ternary mixtures, the following general conclusions can be presented:

- Despite of the verified SCC general mechanical properties degradation in all mixtures with MIBA, at the replacement level of 30% (C10FA20MIBA and C20FA10MIBA) it may be possible to obtain improvements with an adequate treatment to MIBA to eliminate high metallic content;
- As for durability, the obtained results showed some disparity in the SCC behavior, probably due to the influence of MIBA on the concrete microstructure;
- In general, the values recorded in capillary absorption are good despite the variation shown by the mixtures with MIBA;
- In terms of chloride penetration, the SCCs with 60% replacement showed slightly favorable values when compared to the remaining concretes with MIBA;
- For carbonation, the mixtures C10FA20MOBA and B20FA10MIBA (30% replacement) are much more advantageous than the 60% replacement level.

This performance loss was mostly due to the ashes' relatively high metallic Al content, which reacted with OH^- ions present in the mixes' solution thus producing expansive H_2 gas (Figure 3). Still, it should be noted that this phenomenon can be mitigated by introducing an additional treatment process capable of reducing the amount of metallic Al (e.g., introduce and improve the effectiveness of the Eddy current separation stage for non-ferrous metals and subject MIBA to an alkaline solution).

Figure 3. Specimens expansion inside the moulds.