

THE USE OF MSWI BOTTOM ASH IN HOLLOW CONSTRUCTION MATERIALS

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Abstract

Municipal Solid Waste Incineration (MSWI) bottom ash has been used to produce hollow building stones under industrial conditions.

Different concrete mixes in which a part of the natural aggregates has been replaced by pre-treated aged bottom ash have been tested.

The stones were tested on their stability, durability and environmental aspects. The results are very promising.

A patent in the name of « Net Brussel » has been granted. Unlike full concrete building stones, these building stones have thin walls from which components formed during curing can migrate out without causing cracking or any other destruction of the concrete stone.

1. INTRODUCTION

The use of bottom ash in road applications has been one of the solutions to avoid dumping it on landfills. « Net Brussel », the company that collects and treats household waste and similar industrial waste in the Region of the Capital of Brussels (1 million inhabitants), and owner of the incineration plant (500 000 T/year), has tried to elaborate another way of recycling bottom ash and more precisely by using it for the fabrication of hollow concrete building stones.

The research from others has proved that concrete mixtures using bottom ash were of bad quality. Cracks in the concrete were detected and this is probably the reason why research has stopped examining this solution of recycling.

Although the production of thin-walled hollow concrete elements requires in general a better concrete mortar condition than the production of full concrete elements, it has been discovered that thin-walled hollow elements do not present cracks. Any component which may form during the curing step of the manufacturing process can migrate out of the thin walls of the concrete stone without this resulting in cracking or other destruction or alteration of the concrete element.

The aim is to produce building stones using pre-treated aged bottom ash as a substitute for gravel. By encapsulating the bottom ash in a cement matrix of sufficient compression strength and of sufficient dimensions, an immobilisation of the pollutants is aimed. This has been checked by studies on technical behaviour (compression strength and secondary side-effects) and on environmental behaviour (increase in diffusion resistance).

2. PRETREATMENT AND MATURATION CONDITIONS

At the incineration plant of Brussels (grate furnace), the bottom ash is cooled in a water-extractor. The large elements (> 120 mm) are separated from the ash. The remaining ash is then elementary de-ironed by means of a magnetic drum.

Two tests were performed on bottom ash that previously had leaked out for about 2 weeks. This allows a good air exposure and a decrease of humidity. The carbonation process is stimulated.

In the first test, the ash was sieved and de-ironed a second time in another installation. An intensive iron separation is important to avoid the formation of rusty spots.

A second test was performed with, beside a de-ironing, a complementary removal of non ferrous materials. This was done to compare the technical and environmental values with the first experiment. An air separation was used to remove the fine non-burned fraction. The bottom ash was broken in a percussion breaker. This was done to compare the differences in behaviour of the stones, made with the two types of bottom ash.

In the two tests, the bottom ash was subjected to a maturation process of at least 3 months. Therefore the organic compounds can putrefy, metals can be converted to less soluble metalhydroxydes and salts can be mineralised to less soluble forms. The heat released by the exothermic reactions results in a decrease of humidity.

3. STUDIES ON TECHNICAL BEHAVIOUR

Stones were fabricated using bottom ash as a substitute for the gravel used in classical stones (1/3 of the weight).

During laboratory tests the compatibility between bottom ash and different types of cement was tested.

The pre-treated and aged bottom ash was fed with water and cement in a concrete mixer at a factory where building stones were made. After several minutes of mixing, the prepared

concrete was poured into moulds and these moulds were vibrated for a few seconds. The resulting elements were then removed from the moulds and cured a first time for several hours in a substantially closed area, in which temperature and humidity rose as a result of the heat and moisture released due to the reaction formed by mixing the different components. The so formed elements are packed and stored and are submitted to a second curing for 7 days under atmospheric conditions. Several thousands of blocks were made with the bottom ash from the two tests (one without and one with separation of the non ferrous metals).

The building stones, which are now ready for use, belong to the 6/1.6 category (compressive strength superior to 6 MPa and apparent specific gravity inferior to 1 600 kg/m³). Their dimensions are 29 by 19 by 19 mm.

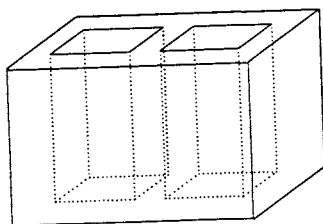


Figure 1 : presentation of the building stones

Their dimensions, their mechanical and their physical characteristics are conform to the Belgian norm BENOR for the production of building stones typically used for indoor applications (NBN B21-001).

No swelling or shrinkage effects occurred. The shrinkage class is less than respectively 0,6 mm/m and 0,4 mm/m (comparable with the values of classical stones) for the first and the second test (with separation of non ferrous materials). Frost resistance was good. The behaviour of alternating wet and dry cycles showed no effect on the stones. Water absorption was a little high in the second test (> 8%), but since no problems with frost resistance or wet & dry cycles has been observed, this does not seem to have consequences.

The compatibility of the stones with interior wall renderings (paints, ceiling coatings and waterproof coatings) was examined during a period of 3 months after application of the coatings. No effects (even with artificial rehumidification) different from those occurring with conventional building stones were noticed. No spots, salt-formations, efflorescence, flaking or blisters appeared.

In the second test, building stones were made with the sieved bottom ash, but also with the broken fraction. The humidity of the broken bottom ash was lower than in the non broken ash. The non broken fraction contained a little more fine material than the broken bottom ash. The compressive strength was a little higher for the stones made with the broken bottom ash than the stones with the non broken bottom ash.

4. STUDIES ON ENVIRONMENTAL BEHAVIOUR

In formed materials, diffusion processes are responsible for lixiviation. Therefore, a test for measuring the diffusion was carried out in order to determine the amount of components released.

Diffusion tests were performed according to the NEN 7345 method, which measures the cumulative diffusion during 64 days.

Test cubes were sawn from the building stones. As the minimum dimensions of 40 mm could not be reached due to the hollowness of the stones, the dimensions of the test cubes were in the first test (on the stones made by bottom ash where the non ferrous metals were not separated) 80 x 80 x 35 mm. The evolution of pH was similar for all the stones, so differences in pH cannot explain possible differences in lixiviation. All parameters were significantly lower than the Flemish project values (in general more severe than the values from the « Bouwstoffenbesluit » from the Netherlands), except for copper where the values were exceeded.

| (mg/m ²) | | | |
|----------------------|-----|--------------------|--------|
| As | 27 | Sb | 6 |
| Ba | 100 | Se | 0,7 |
| Cd | 1,1 | Sn | 20 |
| Cr | 55 | V | 86 |
| Co | 8,5 | Zn | 90 |
| Cu | 25 | Br - | 30 |
| Hg | 0,8 | Cl - | 36 000 |
| Mo | 11 | CN - | 7 |
| Ni | 15 | F - | 360 |
| Pb | 60 | SO ₄ 2- | 27 000 |

Table 1 : lixiviation limits in formed materials according to the Flemish project

For lead and zinc the best immobilisation was reached. The lixiviation of chrome and sulphate were diffusion-controlled. The high values found for the lixiviation of copper indicate that part of it is present in a mobile chemical form. Wash-up and exhaustion effects are the limiting factors for this lixiviation behaviour.

A second test was performed (on stones made using bottom ash from which non ferrous metals and the non-burned fraction have been separated) on cylindrical test samples with a diameter of about 10,5 cm where only the upper circle was not imbedded in an acryl resin. This was done in order to avoid exhausting effects detected in the first test. For none of the metals lixiviation values could be measured. The calculated values were made with the detection limits as values, and have to be considered as ceiling values. The measured values were lower than the calculated values, but both were beneath the values fixed for the Flemish Region.

There were no differences observed between the building stones using broken or using non broken bottom ash.

In parallel with the second diffusion test, test samples made with 8% cement and the same pre-treated, aged bottom ash were also subjected to a diffusion test. In order to simulate the lixiviation behaviour of bottom ash used in bound applications as foundations from road constructions. The critical parameter was copper that exceeded the Flemish lixiviation limits for bound applications.

5. CONCLUSIONS

The recycling of bottom ash in hollow concrete building stones is technical and environmental viable. The thin walls of the stones allow the components formed during curing to migrate out without causing cracking or any other destruction of the stones.

The bottom ash used to make these stones has to be de-ironed to avoid rusty spots and has to undergo a separation of the non ferrous metals to avoid exceeding values on environmental limiting values. Before the treatment the bottom ash is preferably leaked out for two weeks to allow a good aeration. After the treatment the bottom ash has to be aged, for instance for 3 months. The stones are fabricated using this pre-treated and aged bottom ash as a substitute for the gravel used in classical building stones.

The compressive strength is high enough for indoor building stones, and unwanted side-effects such as lack of frost resistance, swelling or shrinkage effects, bad behaviour after wet and dry cycles and non compatibility with interior wall renderings are absent.

No technical nor environmental problems were observed for the building stones in which broken bottom ash instead of non broken bottom ash was used.

The use of bottom ash to fabricate hollow concrete building stones is a good technical and environmental solution to avoid dumping it on landfills and to recycle materials. The diffusion tests have shown that the only possible critical parameter in building stones is the lixiviation of copper, but that this is, after a good separation of non ferrous metals, probably completely resolved.

5. REFERENCES

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