THE USE OF WASTE MATERIAL IN CONCRETE PRODUCTS

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SUMMARY

Aiming at useful applications of waste material, in particular ashes from household refuse incinerators, research was done by the Public Works Department of the Municipality of Rotterdam together with the municipal refuse and transport authority (Roteb), the concrete products company Biemans in Oosterhout and the concrete slab producer HBT in Dordrecht, in replacing natural aggregate by Roteb incinerator ashes in concrete paving blocks and paving slabs.
On a small scale the percentage of ashes and cement were varied. The blocks and slabs produced were tested according to the standards NEN 7000 and NEN 7014. Small test sections were constructed in an urban road with light traffic and an industrial road with heavy traffic.
Based on the tests and experiences a demonstration project with 6750 m2 of paving blocks and 525 m2 of paving slabs was carried out in 1983.
The paper describes the research done and the experiences at sieving the ashes as well as the demonstration project.

1. INTRODUCTION

The use of waste material in concrete is not a new phenomenon. Without a detailed historical review the use of brickwork rubble to replace natural aggregate in concrete in the fifties is mentioned here.
A revival of the use of waste material in the building industry started in the seventies. Causes for this development are the growing concern on the limited availability of natural resources, the environmental effects of the production of natural materials and the increasing quantity of waste with usable properties.
In the last decade in the Netherlands a strong development can be noticed in the field of using concrete- and brickwork rubble in road foundations and the use of recycled asphaltmaterial. Due to an increasing use of coal for energy generating facilities, the interest for applications of pulverized fly ash in concrete has grown.
The treatment of household refuse in the Netherlands consists for about 40% (of the household waste generated) of incineration. The incineration capacity for household waste in this country is about two million tons a year. For the Rotterdam area this figure is about 900,000 tons a year. The residues of incineration are incineration ash (about 25% by weight) and fly ash (about 3% by weight). The installations in Rotterdam produce about 250,000 tons of ashes (fig. 1) each year. The usual market for these ashes lies in roadbuilding, as a foundation or structural fill material.



Figure 1: Close-up of incineration ash

In the last few years a distinct stagnation in the traditional market has grown caused by the economic recession, some doubts about the environmental consequences of using ashes and last but not least the availability of alternative materials like crushed concrete and brickwork.

In the seventies tests have been made to use incinerator ashes in concrete and concrete products. An example of the use of these ashes in concrete is mentioned in (1), the realization of an agricultural road in Lelystad in 1979. This road was about 300 m long and 3 m wide.

The construction thickness was 0.26 m. The concrete mix used consisted of 1400 kg of ashes per m3, which is about 360 kg per m2.

Using ashes in concrete products has started with concrete paving blocks. The first tests have been carried out by the firm Krekel, with incinerator ashes of the installation in Dordrecht. The results of laboratory tests showed a decrease of the flexural strength with increasing replacement of the natural aggregate by ashes, related to paving blocks without ashes. The behaviour of the concrete paving blocks with ashes in the field was not unsatisfactory. It has to be noticed that systematical observations of the tests and the field experiments are not available.

Using the qualitative experiences of the tests mentioned before as a starting point, an investigation was started in 1981 by the Public Works Department of the Municipality of Rotterdam (GW), together with the municipal refuse and transport authority (Roteb), to look into the possibilities of using ashes from the incineration plant of the Roteb in concrete products like paving blocks, paving slabs and other products. The main purpose of this investigation was to examine the feasibility of a structural solution for the stagnating market for ashes by applications in concrete.

This paper deals with the investigation mentioned and the projects carried out. In part 2 the investigation is described. A demonstration project with its experiences are mentioned in part 3. In part 4 some conclusions of the activities up till now are given.

2. PRELIMINARY RESEARCH

2.1 General remarks

The investigation started in 1981 by producing some 2500 test paving blocks, size 213 x 105 x 90 mm, by the firm Biemans in Oosterhout, ordered by GW. The test blocks were fabricated with different percentages of replacing natural aggregate by ashes. At the same time some 1200 test paving slabs, size 300 x 300 x 50 mm, were produced by HBT in Dordrecht, with different percentages of ashes too. The ashes used were from the Roteb incineration plant. This plant produces about 60,000 tons of ashes per year. In the installation a separation of iron parts in the ashes takes place as well as sieving to a size smaller than 20 mm. A size distribution of the ashes from the installation is given in figure 2.

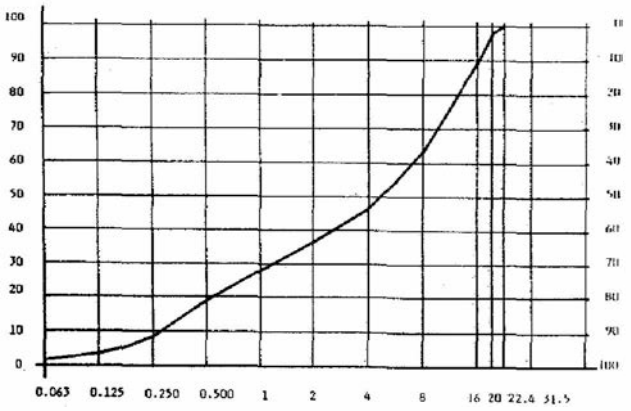

Figure 2: Size distribution of ashes from the Roteb plant

In a separate sieving operation the ashes to be used for the test production were sieved to the 2-8 mm fraction. The experiences at sieving are discussed in 2.2.
After production the blocks and slabs were tested in the laboratory of GW under the standards in use for paving blocks and slabs with natural aggregates. The testresults are discussed in 2.3.
With a part of the blocks and slabs produced, a test section in Rotterdam was constructed. This test section is situated in an urban road with rather light traffic. A view and details of the test section are given in figures 3, 4 and 5.
In 1982 a number of about 10,000 paving blocks has been produced on instruction of GW. These blocks were fabricated with a 20% replacement of the natural aggregate by ashes. The cement contents of the concrete mix was varied. These blocks were tested also in the laboratory. Test results are mentioned in 2.3.
About 120 m2 of test section has been constructed with these blocks in an industrial area in Rotterdam with heavy traffic.
In 1983 about 300,000 paving blocks and about 5000 paving slabs have been produced for a demonstration project. The blocks were fabricated with different percentages of ashes from the Roteb-plant. The test results are discussed in 3.
A number of paving block producers has experimented with Roteb-ashes in 1983. The fraction used was 5-8 mm, in a single case 3-10 mm. The use of ashes in sizes larger than 8 mm has been tested in other concrete products like kerb stones.



Figure 3: General view of test section in urban road



Figure 4: Close-up of paving block with 20% ashes



Figure 5: Close-up of paving block with 60% ashes

2.2 Experiences at sieving the ashes

An open sieving plant was used in sieving the ashes to the fraction wanted for the concret blocks and slabs. Sieving for the first test series was carried out in rainy weather. A rather large quantity of material smaller than 5 mm sticked to the 5-8 mm pieces due to the humidity. The flexural strength of block from the first series was influenced in a negative sense particularly by the fraction smaller than 5 mm. The usable fraction 5-8 mm was about 10 % of the original amount of ashes.
For the second test series the sieving took place in dry weather conditions. The fraction 5-8 mm was obtained well.
Sieving the ashes for the first and second test series was carried out with plate sieves. The sieving for the demonstration project mentioned in 2.1 took place with plate sieves partly. A large part was sieved in the first place with a slotted sieve. The choice was based on the expectation of reducing the risks of sticking of fine material in rainy weather circumstances.
A negative consequence of this choice turned out to be a large fraction of oblong parts of the ashes larger than 8 mm like glass-, earthenware - and metal parts in the sieved fraction. This part was resieved with plate sieves.

2.3 Test results of the first and second series

Paving blocks and slabs from the first test series were tested according to the standard NEN 7000 and NEN 7014. A number of blocks were tested for durability. Blocks from the second series were tested only to the NEN 7000.
In Table 1 a few testresults are given together with some testresults of paving blocks and slabs with natural aggregates as well as the standard figures from NEN 7000 and NEN 7014.
Remarkable is the fact that the characteristic flexural strength of the blocks with 20% ashes from the first series is distinctively lower than the figure from the second series with the same amount of ashes and cement. In particular the size distribution of the ashes in the first series - with a large amount of fine material - is thought to be responsible for this result. showes from the second series that a small variation of the cement content is hardly noted in the flexural strength.
Compared to the results of blocks without ashes the standard deviation shows no significant difference.

Table 1: Test results first and second test-series

	replacement of aggregate by ashes (%)	change in cement-content (%)	flexural strength $\bar{x} - 1{,}65\ S$ (N/mm^2)	standard deviation S	skid resistance SRT
series 1					
paving blocks	10	-	5.1	0.36	89-93
	20	-	4.3	0.35	83-93
	30	-	3.7	0.72	89-91
	60	-	4.0	0.33	87-93
paving slabs	11	-	6.3	0.40	
	22	-	5.5	0.29	
	33	-	5.5	0.28	
	50	-	5.0	0.26	
series 2					
paving blocks	20	- 5	6.1	0.63	64-74
	20	-	6.2	0.65	63-78
	20	+ 5	6.3	0.76	62-78
blocks without ashes	-	-	6.0	0.63	83-87
slabs without ashes	-	-	6.3	0.27	
NEN 7000			5.9		
NEN 7014			5.5		

From the durability tests carried out on blocks of the first test series it showed that these blocks are heavily attacked by hydrochloric acid (3-10 %). The persistence against salt and alkali is good as well as the freeze-thaw behaviour of the blocks. It has been noted that with an increasing amount of ashes the dimensional tolerances are increased, in particular those of the paving slabs.

The first and second test series as well as the blocks and slabs for the demonstration project were produced with blast-furnace cement.

Based on the results and experiences from both test series it was decided in 1983 to use paving blocks and paving slabs with Roteb ashes in a demonstration project in Rotterdam.

3. DEMONSTRATION PROJECT KEILEHAVEN

A suitable opportunity to use paving blocks and paving slabs with ashes was offered in a project ordered by the Roteb to be realized in 1983 and consisting of a transfer facility for household refuse, offices and garages. The area to be paved was about 6750 m2 of paving blocks (213 x 105 x 90, 213 x 105 x 120) and about 525 m2 of paving slabs (300 x 300 x 80 mm). The number of blocks and slabs is about 300,000 and 5000 respectively. The amount of ashes to be used in the blocks and slabs was sieved in the fraction 5-8 mm as described in 2.2. The size distribution of the ashes used for production is given in figure 6.

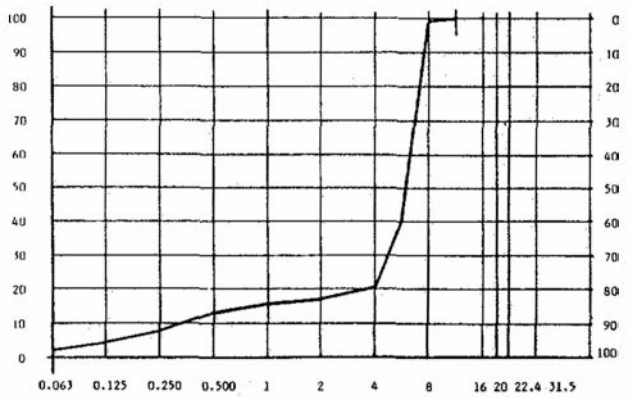

Figure 6: Size distribution of ashes used for paving blocks and slabs

Together with the Roteb it was decided to apply paving blocks with 0%, 10%, 20% and 40% replacement of the aggregate by ashes. The paving blocks were produced by the firm Biemans in Oosterhout in spring 1983. They were tested by the laboratory of GW. Some test results are shown in Table 2.

The project was carried out in the summer of 1983. Experiences at the paving activities were not clearly different from conventional projects. A few remarks were heard about glass- and metalparts in the surface of the paving blocks. In general no problems were met. Pictures of the roadsurface near the transfer facility can be seen in figure 7 and 8.

Table 2: Test results paving blocks demonstration project Roteb

	replacement of aggregate by ashes (%)	flexural strength $\bar{x} - 1{,}65\ S$	standard deviation	skid resistance
paving	0	6.8	0.18	65-72
blocks	20	6.1	0.34	68-72
	30	5.1	0.31	-
	40	4.1	0.24	73-83



Figure 7: General view of paving blocks in transfer facility



Figure 8: Close-up of paving blocks with 40% ashes

The paving blocks and paving slabs in this project will be monitored in time. A good comparison with paving blocks without ashes is possible.

4. INTERIM CONCLUSIONS

As mentioned the test sections of the first and second series as well as the demonstration projects are rather recent. The following conclusions are therefore provisional.

- the use of incinerator ashes as a replacement of natural aggregates in concrete blocks and concrete slabs is technically feasible;
- the fraction of the ashes that can be used is 3-10 mm; in particular the fraction smaller than 3 mm has to be removed;
- the ashes have to be de-metalized properly; the organic residue has to be small (lower than 5%);
- the amount of glass present in the ashes (in the experiments up to 20%) is not prohibitive;
- with a replacement of 20% of the aggregate by ashes the standards for blocks and slabs with natural aggregate can be met; a further optimalization may show a higher ash content possible;
- only a limited quantity of the amount of ashes produced will be applicable in concrete products.

(1) Gels J.A., Bakker R.F.M., Leeuwis M., Met afvalverbrandingsslakken vervaardigd beton in de wegenbouw; Wegen, 4 (1980), p.99-105.