

THE APPLICATION OF INCINERATOR BOTTOM ASH IN ROAD CONSTRUCTION

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Abstract

Today Municipal Solid Waste Incinerator Bottom Ash is to a large extent used in road construction on Denmark. It is primarily used as fill in embankments and as granular subbase course. This is the result of development during the last 20 years; at the same time incineration of waste has become an substantial element in the handling of waste in Denmark.

The use of bottom ash as subbase in light and medium trafficked roads, paths and parking areas has proved to be successful. In 1993, a more heavily trafficked test road was constructed. Layers of 20 cm bottom ash from various plants was used as subbase and compared to the standard material which is virgin, relatively uniform sand.

After 3 years of medium to heavy traffic, the test road shows no signs of rutting or progressive damage or other signs of rapid deterioration of the road construction. However, a period of 3 years has been estimated to be too short to recommend general use of bottom ash in heavily trafficked roads.

This paper treats the results from the test road and the Danish experience gained from the use of incinerator bottom ash in road construction.

1. Introduction

Municipal Solid Waste Incinerator Bottom Ash (MSWI bottom ash or bottom ash in following) is the solid residual product, which is found at the bottom of the incinerator in plants used for burning municipal solid waste. Incineration of municipal solid waste is an integrated part of the Danish way of handling waste. The general priorities are: 1. Minimise waste production, 2. Recycle, 3. Incinerate, 4. Dispose in landfill.

In the 1970'ies and 1980'ies several examinations were carried out in Denmark to describe the properties of MSWI bottom ash for construction purposes. The main result of the tests was that sorted bottom ash is well suited as subbase for lightly trafficked roads, parking areas, paths and other trafficked areas. Tests also showed that bottom ash can be used as fill material for embankments.

The amount of waste which is delivered to incinerator plants has increased in recent years. Based on information for 1994, the annual amount of waste delivered to the 31 incinerator plants in Denmark is 2.1 mill. metric tons. The incineration process results in a weight reduction of some 75%. After a cooling and storage period, magnetic metals and larger particles are removed, so that the remaining ash, sorted bottom ash, can be used for building and construction works.

Since the road sector is one of the largest consumers of sand, gravel and stone materials, it has been this sector which has used the major part of the bottom ash produced in Denmark.

Ten years ago, the State has introduced taxes to stimulate recycling: Today, ECU 28 per ton is charged for incineration in plants which produce both electricity and heating whereas a tax of ECU 35 per ton is charged for plants that only produce heating. For depositing waste, the tax is ECU 45 per ton, and from 1997, it is not allowed at all to dispose waste which can be burnt.

2. Recycling as subbase material

The results of the tests and investigations which were carried out in the early 1980'ies by Schmith (ref. 1 and 2) showed that it is reasonable to use bottom ash as subbase for lightly trafficked roads and areas. Based on this information counties and local authorities have used considerable amounts of bottom ash as general fill and as subbase layer. The use is typically concentrated in construction projects which take place in the same county as the incinerator plant.

The experiences gained from the construction phase are positive. In general, the sorted bottom ash can easily be handled and laid, on condition that the moisture content in the bottom ash is close ($\pm 3\%$) to the optimum moisture content, and measurements have documented that strengths can be obtained which are fully satisfactory for the construction job.

Since 1989, the construction projects for light traffic, where bottom ash has been used, have been carried out based on Material Specifications and Working Specifications (Pihl et al. Ref. 3). Regulations from 1983 based on public law issued by the Ministry of the Environment restricted the permits for the use of bottom ash seen from an environmental point of view.

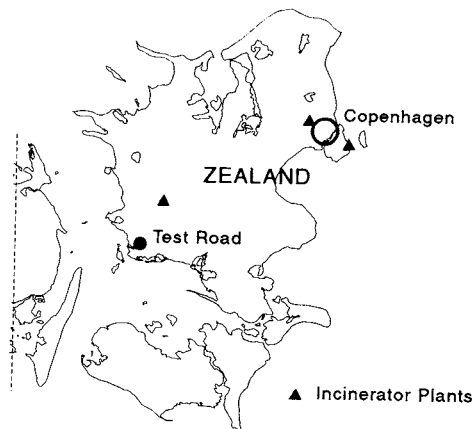


Fig. 1 Map of Zealand, showing actual incinerator plants and the test road.

3. Test road 1993

To investigate a possible use of sorted bottom ash for moderate to heavy traffic, a full scale test was carried out in 1993. The test sections are situated on a newly constructed ring road passing the town of Skælskør on Zealand, see Fig. 1. The starting point was a traditionally constructed road on a subgrade of normal Danish moraine clay. The test road was constructed in 1993, a total of 2.3 km with a cross section as shown in Fig. 2. The traffic load was predicted to be moderate to high with many relatively heavy vehicles.

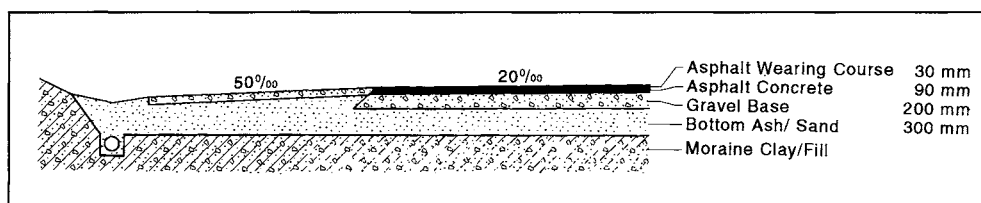


Fig. 2 Cross section of the test road

Four sections of 200 m each were given a different subbase material; three different bottom ashes, from the Amager Plant, Vestforbrænding Plant and KAVO Plant - and a traditional material - relatively uniform sand - as a reference material all used as subbase material.

A private enterprise AFATEK was responsible for running the project; furthermore the Danish VKI (Water Quality Institute) and the Danish Road Institute participated in the project. The project period was from Spring 1993 to Autumn 1995 and later the Danish Road Institute has kept the test sections under observation and carried out tests on the road.

4. Laboratory testing

The aim of the tests in the laboratory was to evaluate the properties of the bottom ash for construction purposes compared to the properties of the reference material. The following tests and material examinations were carried out: Grain size distribution (Fig. 3), grain density,

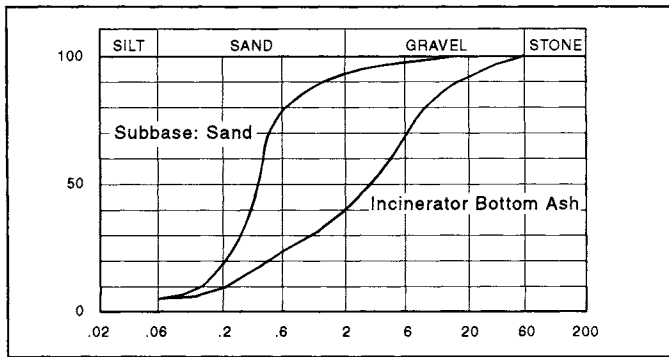


Fig. 3 Grain size distribution for sorted bottom ash and sand (average value)

compaction test and CBR-tests, Los Angeles tests, loss of ignition, etc. Furthermore, freeze-thaw properties, permeability, capillarity were also examined.

Some of the material tests were carried out at the time of delivery before laying on the road site, some after laying and others after 1 and 2 years in operation; materials were taken from all test sections.

An important result from the analyses of the bottom ash was that crushing during construction work was apparently the strongest influence on the material, stronger than the influence of traffic in the following two years on the completed road. Some vibration tests in the

Test		A	B	C
Grain density fraction 0 - 16 mm	ρ_s (t/m ³)	2.51-2.52	2.65-2.67	2.57-2.58
Loss of ignition 1000°C fraction 0-1 mm	GI (%)	14.8-14.9	11.3-11.8	15.4-16.7
Los Angeles according to ASTM C131	LA (B) (%)	53	53	45
	LA (C) (%)	46	49	48
Vibration dry density and moisture content according to ASTM 2049-69	$\rho_{d,max}$ (t/m ³)	1.54-1.55	1.65-1.67	1.54-1.54
	w_v (%)	22.7-23.0	20.3-20.5	23.3-23.3
A: Bottom ash, Amager Plant B: Bottom ash, Vestforbrænding Plant C: Bottom ash, KAVO Plant				

Table 1: Laboratory tests of sorted bottom ash

laboratory showed that crushing was particularly big when the material was dry, reduced when it was wet, and least when the material was almost water saturated.

The permeability of the bottom ash was measured in the laboratory according to the principle of measurement on water saturated materials with decreasing water pressure. The permeability of the bottom ash was five to ten times lower than that of the reference material (sand material).

Bottom ash / Sand	Permeability ¹⁾ m/s
Amager Plant	0.5-0.7 x 10 ⁻⁶
Vestforbrænding Plant	0.9-1.4 x 10 ⁻⁶
KAVO Plant	0.2-0.4 x 10 ⁻⁶
Sand	7 - 8 x 10 ⁻⁶
¹⁾ Measured on water saturated material with decreasing water pressure	

Table 2: Permeability from laboratory tests

5. Tests on the road

The aim of the tests on the road was to evaluate the functional properties of the bottom ash material. The purpose was also to observe any special conditions which appear when handling bottom ash including spreading in layers, regulating and compacting. In the construction period the subgrade, subbase and the basecourse was controlled according to current specification, in regard to material control and compaction. Isotope measurements were carried out to control the compaction of traditional materials, while it was necessary to use the sand replacement method in order to determine the degree of compaction of bottom ash.

For the measurement of the traffic, equipment was installed to make it possible to measure vehicles and axles continuously, and during the first two years all vehicles were weighed on two different days. The traffic volume on the two-lane road was converted to an ADT of

approx. $5.5 \cdot 10^4$ equivalent 10 ton axles in the one direction and approx. $3.0 \cdot 10^4$ equivalent 10 ton axles in the other direction, which is considered to be moderate to heavy traffic according to the terminology of the Road Standards. The difference in the traffic volume in the two directions is due to the fact that there is a brewery at the end of the road, so that heavily loaded vehicles leave the factory. They return to the factory empty.

Bearing capacity was measured by means of static plate bearing tests on the subgrade, on the layer of bottom ash and on the reference layer as well as on top of the unbound gravel basecourse. Four times during the period the completed road was measured by means of the Falling Weight Deflectometer. The following conclusions can be drawn from the static plate bearing tests: The average E-value for the bottom ash is 81 MPa and the bearing capacity of the material is therefore at the same level as that of the reference material consisting of sand, with an average E-value of 79 MPa. Bottom ash from Vestforbrænding Plant has on average the highest E-value. The same pattern can be seen for the dynamic E-values (from the Falling Weight Deflectometer measurements): Amager bottom ash and KAVO bottom ash have significantly lower E-values than Vestforbrænding bottom ash and the reference material (sand).

In order to prove the form stability and structural quality of the bottom ash and therefore its suitability as an element in road construction, measurements of evenness and rutting on the road surface were carried out (longitudinal and transversal evenness). Comparisons between the sections with bottom ash and the reference section should prove its suitability. The following conclusions can be drawn regarding evenness and rutting: There was no difference in evenness between the four test sections, three with bottom ash and one with sand as subbase material. There was no significant change in rutting in the project period for the four test sections. The measured mean values were small and in practice within the uncertainty of measurements. According to these facts there was no visible damage, unevenness or rutting on the road sections.

The conclusion showed that there was no difference between the sections with bottom ash and the reference section.

6. Conclusions

After three years of relatively heavy traffic on the test road no rutting, development of damage or other signs of rapid deterioration of the road construction has been observed. Recycling of MSWI bottom ash as subbase material for lightly trafficked roads and other areas can therefore continue, seen from a road construction point of view. However, the most recent examinations have resulted in consequences for continued use.

The relatively low permeability which has been measured on the bottom ash materials has resulted in a recommendation: no use must take place in connection with difficult moisture and subgrade conditions, where the bearing capacity of a road construction is dependent on quick drainage. Since loss of ignition is not thought to be suitable as evaluation for the properties of bottom ash as subbase material, this has been replaced by other limits for unburnt matter in bottom ash. It is also necessary to change the present general construction specifications, so that excessive compaction and unnecessary traffic directly on top of the bottom ash is kept to a minimum, in order to avoid that the bottom ash is crushed too much during laying, compaction and later in the construction process.

Three years is considered to be too short a period to give a general recommendation regarding the use of MSWI bottom ash on moderate to heavily trafficked roads. The relatively low measured E-values (bearing capacity) and the lower permeability in relation to traditional road materials are negative conditions which must be considered. It has, however, been decided to continue observations of the test road.

7. The future

Since there are good results of the use of Danish MSWI bottom ash as fill in the construction sector, recycling of the material in this way will continue in the future. The evaluation of the latest laboratory and test road results lead us to the conclusion that Danish MSWI bottom ash under certain conditions can also continue to be used as subbase in roads, paths and other trafficked areas.

New Material Specifications and General Construction Specifications were approved in 1996 (Pihl and Milvang, Ref. 4). The present environmental demands are expected to be changed in the near future. Possibly more stringent rules will be seen for use of bottom ash in areas of great interest for drinking water, but it is not expected that this will have any influence on the continued use of bottom ash as fill and subbase material in the Danish road sector.

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