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USE OF INCINERATOR BOTTOM ASH AS FILLING MATERIAL UTILISATION DE MACHEFERS COMME MATERIAU DE REMBLAI

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SYNOPSIS: In Sweden, 400,000 tons of incinerator bottom ash are produced per year. Roughly 250,000 tons can be reused, especially as filling material. Actual utilization is, however, very low as there are no simple rules or procedures to follow when applying for official environmental approval for a particular project.

A large-scale project has been performed in Sweden with the aim of achieving a more regular use of bottom ash based on proper technique and simplified procedures. The study involved both physical properties, in particular the behaviour of the material in road construction, and assessment of environmental impact.

The study comprised ashes from two different plants. This paper primarily describes the test results from using pre-sorted incinerator ash in the test road in Malmö.

BOTTOM ASH

At the Malmö plant, sorting of the bottom ash takes place after the surplus quenching water has drained off. The sorting includes screening and magnetic separation. After this sorting activity, about 70% of the bottom ash can be regarded as a possible substitute for gravel-like materials. The grain size distribution of this fraction is shown in Figure 1. The remaining 30% from the sorting operation contains about one third of large scrap that can be sold, while the rest normally has to be landfilled.

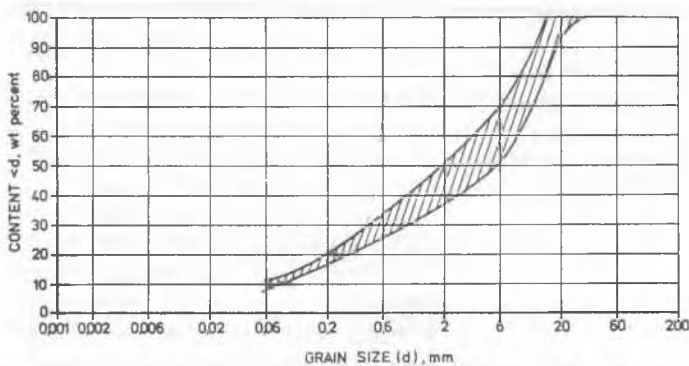


Fig. 1. Particle size distribution of sorted ash from the Malmö incinerator plant.

A classification of the sorted bottom ash has been made (Jacobsson, 1989) and is shown in Table 1. The content is shown for different grain size intervals. As can be seen from the table, about 40% is a glassy material.

Table 1. Main components in a sorted bottom ash used in Malmö (Jacobsson, 1989).

	FRESH ASH			AGED ASH		
	FRACTION			FRACTION		
	5.6-8 mm	8-11.2 mm	11.2-16 mm	5.6-8 mm	8-11.2 mm	11.2-16 mm
	WEIGHT %			WEIGHT %		
Magnetic	-	-	-	-	-	-
Non-magnetic slag	45.0	55.6	50.6	43.4	37.9	28.5
Glass	44.9	40.0	35.9	49.0	49.7	56.6
Ceramic material	1.3	2.4	3.4	2.3	3.9	5.0
Stone	8.7	2.0	10.1	5.3	8.5	9.9
Paper	0.1	-	-	-	-	-

Bottom ashes from incineration change properties with time due to drainage, CO₂ uptake and hydrogen production caused by an excess of aluminum. Also oxidation of iron may change the properties (Aubry et al, 1986). Experience in Europe is that such storage leads to a more stable product (Hartlén, 1988). In West Germany it has been found that temporary storage prevents the ash from future swelling (Merkblatt, 1986).

The water content of the fresh ash (about one to two months old) before laying was about 23% and for one year old ash about 16%. However, the water content varies considerably.

TEST ROAD

A test road was constructed close to the incinerator plant in Malmö. The road is almost 500 m long och 9 m wide and was built in 6 sections, each 80 m long. The road is an internal road at the incineration plant, used by about 300 heavy trucks per day.

Both fresh and aged ash was used in the construction. One section was built with natural frictional material, following normal design rules, to be used as a reference. The configuration of the different sections is shown in Figure 2. Ash was used not only underneath the bituminous layer, but also in the embankment slopes. Note that the asphalt layer and the base course material vary in thickness. The subsoil consists of old fill material of various types.

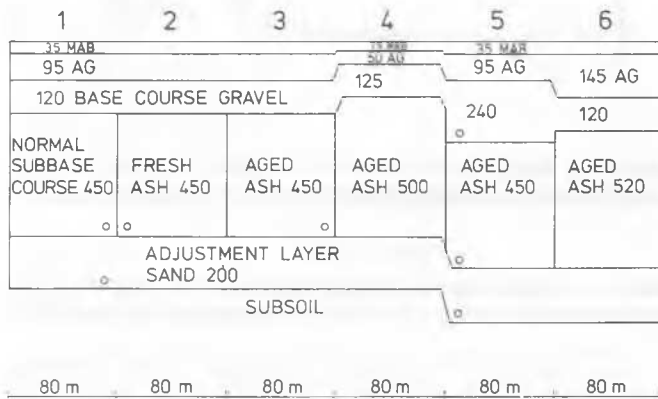


Fig. 2. Test road built up in six different sections. *o* denotes placement of leachate collection tubes.

To measure the environmental impact of the ash gravel in the road, leachate collection devices were installed in the different sections. The collection devices were placed in the road underneath the subbase course, and in one section also below the base course and the adjustment layer.

Surface run-off water is collected in boxes at the lower edge of the inclined road and a leachate collection device was also placed along the road in the embankment slope. The flow measurements were made with a tipping bucket system and automatic sample collection, type SGI (Lundgren & Hartlén, 1991). Leachate collection was started in December 1988. The data presented refer to a 350-400 day sampling period.

Physical Properties

In the laboratory, compaction tests were performed on fresh ash-gravel, ash-gravel 1 month old and an aged ash-gravel (over 1 year old). As shown in Figure 3, a clear compaction curve with a well-defined peak was obtained only for the aged material. However, the maximum recorded values are of the same order of size for the different ages of ash-gravel, i.e. 1.79 to 1.82 t/m³.

A comparison between field and laboratory compaction tests shows that compaction in the laboratory with heavy compaction resulted in greater crushing than that actually obtained in the field. The same conclusion has earlier been drawn in the case of coal slag. A recommendation is therefore to study the degree of crushing in the field through Standard Proctor compaction or vibratory compaction in the laboratory.

The aged ash was easy to compact without any indications of instability. The compaction resulted only in minor crushing of the particles, increasing the content of fines by a few per cent. This means that the material can be regarded as a draining material also after compaction.

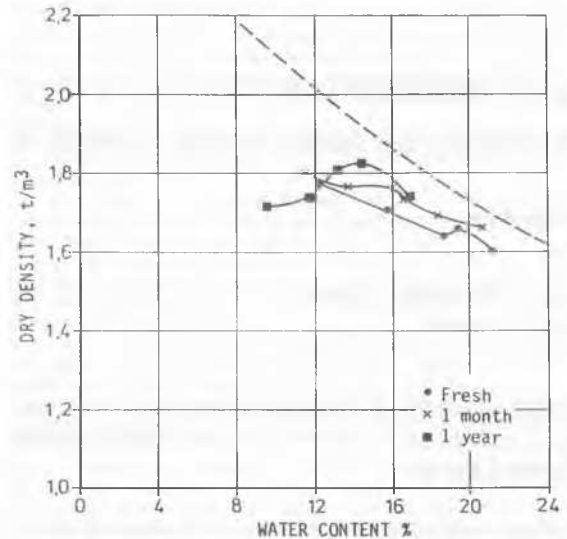


Fig. 3. Compaction curves (modified Proctor) of sorted bottom ash of three different ages (Hartlén & Rogbeck, 1989).

During compaction, the higher water content in the fresh ash-gravel led to a loss of bearing capacity in the fill. A ground failure occurred under the 4.3-ton roller. This phenomenon can also be obtained in natural fine-grained soils when the water content exceeds the optimal level by 3-5 per cent units according to modified Proctor compaction.

To investigate the bearing capacity of the road, the Swedish Road and Traffic Research Institute (VTI) carried out falling weight deflectometer tests (FWD). Based on these tests, the modulus of elasticity (Young's modulus) can be evaluated for the test road in total as well as for the individual layers. 16 tests were made on each section. The results are shown in Figure 4.

Paving and Base course gravel	1352	1157	1053	589	771	1688
Embankment mean	332	339	270	215	325	513
Subbase course						
Adjustment layer and Subsoil	117	134	98	121	119	133

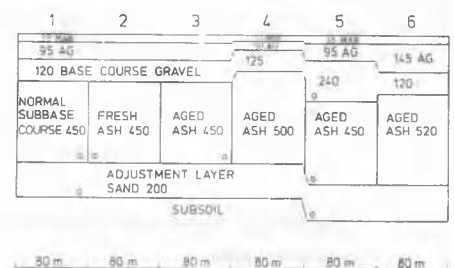


Fig. 4. Modulus of elasticity based on falling weight deflectometer tests performed by VTI (Jacobsson, 1989).

The results so far show that most of the sections have good bearing capacity. The difference between the reference section and the best

sections with ash is within the error of measurement. An increase in thickness of the paving or the base course material results in a significant increase in the total stiffness of the road. In regard to the subbase material, small differences in the modulus of elasticity are shown between natural frictional material (a sandy gravel) and fresh and aged sorted bottom ash.

After the test embankments had been finished, filling work was performed adjacent to a test compaction area for a bridge abutment. The embankment was compacted with a 10-ton vibrating roller, 0.55 m layer thickness and 6 roller passes. i.e. in the same way as the test embankment. The total depth of the fill was about 3.0 m.

In order to determine the stiffness, pressuremeter tests were performed at three depths, corresponding to 0.9, 1.8 and 2.7 m. Owing to the limited area of the fill, only one successful hole was made. In this hole, pressuremeter moduli of 33, 39 and 30 MPa were measured. These values indicate that the fill is firm. In order to achieve such a high firmness, chemical reactions must have taken place in the fill after compaction, resulting in hardening. The firmness of the ash-gravel corresponds to that obtained in compacted rock fills and is greater than that obtained in a compacted sand fill. However, it should be noted that experience so far is limited in the case of ash-gravel fills. Nevertheless, the pressuremeter tests show that it should be possible to obtain a very firm fill when using slag from incinerator plants.

Environmental Impact

The environmental properties were studied by conventional shaking tests as well as special diffusion tests, performed in the SGI laboratory. Both tests indicate that the leachate content will decrease comparatively rapidly with time. There was not a great difference in this respect between the salts (sulphate and chloride) and metals in general (Kullberg, 1990). Some metals differ from the general pattern, however.

The laboratory tests were compared with leachates collected in the field. There are differences which especially refer to the lower pH-value in the field leachates. The great influence of the pH-value has been shown by van der Sloot (1991).

A general assessment of the effect that graded bottom ash fill may conceivably have on the nearest (most sensitive) watercourse can be made if a number of assumptions are taken:

- * The formation of leachate corresponds to the percolation through permeable fractured asphalt (100 mm/year).
- * Sorption of transported elements corresponding to 50% takes place in the underlying soil.
- * The leachate is diluted only with such surface water and ground water as have formed in its "own" runoff area.
- * No sorption in the surface watercourse of the substances in question from the bottom ash is expected.

Dilution of the leachate in the internal runoff area and thereby in the soil layers and eventually in the local surface watercourse, will naturally depend on the size of the runoff area. In most cases, however, dilution corresponding to a factor of at least 100 within reasonable distance of a sizeable fill is likely to be achieved. If the background level is assumed to correspond to that in unaffected watercourses, then the increased levels can be calculated as shown in Table 2. A corresponding

Table 2. The "normal" chemical composition of the leachate from sorted slag is assessed on the basis of the project results as well as on the corresponding "unaffected" background content in surface water and the calculated content resulting from the discharge of leachate into local watercourses (Hartlén & Lundgren, 1991).

Substance/ parameter	Content in leachate from graded slag	Content background surface water	Content local watercourse	Contamination factor
Chloride (mg/l)	120	4	5.1	1.3
Sulphate (mg/l)	300	15	17.8	1.2
Aluminium (µg/l)	50	30	30.2	1.01
Cadmium (µg/l)	0.5	0.02	0.025	1.2
Chromium (µg/l)	4	0.3	0.34	1.1
Copper (µg/l)	20	0.7	0.89	1.3
Nickel (µg/l)	25	0.5	0.74	1.5
Lead (µg/l)	10	0.2	0.30	1.5
Zinc (µg/l)	100	2.0	3.0	1.5

contamination factor following the National Environment Protection Agency's "General Advice" (1990) can be assessed in the watercourse.

In spite of the conservative assumptions in the calculations, the contamination factor for nickel, lead and zinc would obviously reach the limit between "insignificant effect" (up to 50% increase) and "significant effect" (50-200% increase). However, it should be noted that this applies to an initial stage before dilution of the leachable part of the residual products starts to occur. A reduction of the leachate content by a factor of 5-10 is obtained after only a few years.

The environmental impact should not be evaluated solely on the basis of concentrations in leachate and thus in the affected ground water and/or surface water. The total amount in grams, for example, is also of importance.

CONCLUSIONS

The conclusion is that sorted bottom ash from incineration has a potential for utilization. The ash can be handled as a natural aggregate and will after compaction result in an embankment with good bearing capacity. The ash must age at least 2-4 months before use and the magnetic material separated.

The environmental impact will be limited. However, the ash must not be used close to ground water catchment areas. Furthermore, the road surface should be covered with an impervious asphalt to reduce the leachate production. Efforts should be made to use further source separation before and after incineration, thus reducing the metal content in the ash.

Finally, the SGI is now developing a system for quality assurance of bottom ash.

ACKNOWLEDGEMENT

The author wishes to thank Stiftelsen Reforsk, who has financed a major part of the studies, and to the plant owner Sysav AB, who has made this study possible.

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