Goumans/Senden/van der Sloot, Editors
Waste Materials in Construction: Putting Theory into Practice

Municipal Solid Waste Incineration (MSWI) Bottom Ashes as Granular Base Material in Road Construction

G. Pfrang-Stotz
Institut für Technische Chemie/Thermische Abfallbehandlung (ITC/TAB)
Forschungszentrum Karlsruhe
Postfach 3640, D-76021 Karlsruhe, Germany
Phone: +49 (0) 7247 82 2952 FAX: +49 (0) 7247 82 4373

J. Reichelt
Institut für Straßen- und Eisenbahnwesen (ISE)
University of Karlsruhe
Postfach 3640, D-76128 Karlsruhe, Germany
Phone: +49 (0)721 608 3869 / FAX: +49 (0)721 60 76 10

Introduction

In the Federal Republic of Germany wastes should, in the first line, be avoided and, in the second line, be recycled or utilized for energy production. When MSWI bottom ash is utilized in road construction as granular base material it has to satisfy the structural engineering requirements, and its environmental compatibility has to be ensured.

With regard to the mineralogical composition [1] four types of bottom ashes can be distinguished:

1. grate ash: material discharged from the end of the grate
2. raw bottom ash: grate ash discharged via a quench tank, containing grate siftings
3. bottom ash: raw bottom ash which had been processed and stored for at least three months
4. aged bottom ash: raw bottom ash which had been stored for several years

In order to evaluate these requirements, mineralogical, chemical and structural engineering methods were applied to raw bottom ashes as well as to processed bottom ashes stored for three months, all originating from 12 municipal solid waste incineration plants operated on different process technologies.

Elution Behaviour (DEV-S4 Test)

The elution behaviour of MSWI bottom ashes is characterized by the German DEV-S4 test [2]. The DEV-S4 test is used for the comperative evaluation of the environmentally relevant properties of industrial by-products based on the crucial limits of national regulations (TL HMVA-StB 95) [3].

The statistical interpretation of a quality controlled MSWI bottom ash shows (Table 1):

- The largest fraction of cations in the solution is made up by calcium, sodium and potassium. The anions are sulfate and chloride.
- The largest standard deviations are refered to the elements calcium, sodium, potassium, chloride and sulfate. These elements build up the soluble salts halite (NaCl) and sylvite (KCl), the sulfates anhydrite ($CaSO_4$) and bassanite ($CaSO_4x0,5H_2O$) as well as carbonates, e.g. Calcit ($CaCO_3$). The high leaching rates of these elements are attributable to these mineral phases, which react very sensitive of modifications of the physical-chemical environment.

- The arithmetic means of the concentrations of the heavy metals, chloride, sulfate and cyanide are clearly below the crucial limits by TL HMVA-StB 95 [3].

A comparison of the elution data (DEV-S4) of MSWI bottom ashes produced in 12 MSWI plants operated on different process technologies shows (Table 2):

- The crucial limits laid down by TL HMVA-StB 95 [3] are conform to the specifications of the values assigned.

Structural Engineering Properties

The statistical interpretation of a quality controlled MSWI bottom ash shows (Table 3):

- The crucial limits laid down in TL HMVA-StB 95 [3] are observed by the MSWI bottom ashes investigated, with exception of the parameter „Resistance to Freezing and Thawing". The low resistance to freeze-thaw-changes can be attributed to the high contribution of low resistant mineralogical attributes such as high porosity, specific mineral composition and relatively weak carbonate bond between the bottom ash constituants.

Based on the results of investigations, the following summarizing conclusions can be drawn for the comparison of MSW incineration bottom ashes produced in 12 MSWI plants operated on different process technologies (Table 4, Fig. 1 and 2):

- The crucial limits laid down in TL HMVA-StB 95 [3] are observed by the MSWI bottom ashes investigated, with exception of the parameter „Resistance to Freezing and Thawing".

- The impact destruction values ($SZ_{8/12}$) of the Impact Test determined as a measure of resistance to mechanical fracmentation are within the limits laid down in TL HMVA-StB 95 [3]. However, a comparison with the impact destruction values of natural mineral substances, i. e. basalt ($SZ_{8/12}$: 9 - 20 wt.%) makes evident that similar stabilities cannot be achieved by MSWI bottom ashes. This is attributable to the relatively weak carbonate bond between the bottom ash constituents and to the specific composition of mineral substances. Thus, a high content of stable silicates and oxides exerts a positive influence on the stability properties whereas high fractions of salts and sulfates reduce the stability.

At present time energy- and cost-effective processes were tested to optimize the mineralogy, the leaching behaviour and the structural engineering properties of MSWI bottom ashes without influencing the present process technology expense for MSW Incineration decisively.

[1] PFRANG-STOTZ, G. & REICHELT, J. (1996): Mineralogical aspects of environmentally relevant and structural engineering properties of municipal solid waste incineration (MSWI) bottom ashes. International Conference on Incineration and Thermal Treatment Technologies, May 6-10, 1996, Savannah, Georgia, U.S.A., 271-277.

[2] DIN 38 414, Teil 4: Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlammuntersuchung: Schlamm und Sedimente (Gruppe S), Bestimmung der Eluierbarkeit mit Wasser (S4), Beuth-Verlag, Berlin, (1984)

[3] Technische Lieferbedingungen für Hausmüllverbrennungsasche im Straßenbau (TL HMVA-StB), Forschungsgesellschaft für Straßen- und Verkehrswesen, Köln, (1995).

Table 1 Statistical Interpretation of Structural Engineering Properties of MSWI Bottom Ash D							
Parameter	Unit	Samples	Arithmetic Means	Standard Deviation	Minimum	Maximum	TL HMVA*
Fines Content	% by mass	27	4,3	1,5	1,4	7,3	max. 7,0
Water Content	% by mass	28	12,6	3	6,7	19,9	
Bulk Density	g/cm³	26	2,65	0,05	2,47	2,76	
Uncompacted Bulk Density	g/cm³	26	1,21	0,06	1,07	1,3	
Proctor Density	g/cm³	13	1,64	0,06	1,55	1,81	
Optimum Water Content	% by mass	13	15,7	1,4	12,2	17,2	
Resistance to Freezing an Thawing	% by mass	16	8,9	3	3,3	15,1	max. 3(5)
Resistance to Fragmentation	% by mass	16	38,9	1,3	35,5	41	max. 40

Table 2 Statistical Interpretation of Elution Datas (DEV-S4 Process) of MSWI Bottom Ash D							
Parameter	Unit	Samples	Arithmetic Means	Standard Deviation	Minimum	Maximum	TL HMVA*
Calcium	mg/l	28	171	59,2	73	331	
Magnesium	mg/l	28	1,6	2,5	0	8	
Sodium	mg/l	28	99,2	48,6	26	220	
Potassium	mg/l	28	40,4	14,2	17	81	
Lead	mg/l	26	0,008	0,01	0,0005	0,037	0,05
Cadmium	mg/l	26	0,0005	0	0,0001	0,0037	0,005
Chromium	mg/l	26	0,038	0,02	0,003	0,088	0,05
Nickel	mg/l	26	0,006	0	0,001	0,022	0,04
Copper	mg/l	26	0,044	0,02	0,01	0,1	0,3
Zinc	mg/l	26	0,034	0,04	0,009	0,2	0,3
Mercury	mg/l	23	0,00014	0,00008	0,00003	0,0002	0,001
Arsen	mg/l	24	0,00018	0	0,00003	0,001	
Chloride	mg/l	28	81,4	30,5	44	170	250
Sulfate	mg/l	28	472	180	230	769	600
Cyanide	mg/l	9	0,02	0	< 0,02	< 0,02	0,02
AOX	mg/l	10	0,029	0,03	0,01	0,083	
pH		28	10,4	0,5	9,5	11,4	7 bis 13
el. Conductivity	mS/cm	28	127	26,1	62,9	175	600

* Crucial Linmits: Technical Supply Terms for MSWI Bottom Ashes (TL HMVA-StB), 1995

Table 3 Structural Engineering Properties of Different MSWI Bottom Ashes														
Parameter	Unit	A	B	C	D	E	F	G	H	I	J	K	M	TL HMVA*
Fines Content	% by mass	3,2	1,7	1,2	4,3	1,9	2,6	2,4	1,3	2,5	2,7	0,6	2,1	max. 7
Water Content	% by mass	7,5	n.b.	n.b.	12,6	6,3	n.b.	6,8	6,1	9,7	7,2	n.b.	n.b.	
Bulk Density	g/cm³	2,7	2,665	2,706	2,65	2,691	2,72	2,658	2,662	2,534	2,68	2,801	2,791	
Uncompacted Bulk Density	g/cm³	1,23	n.b.	1,195	1,21	1,162	n.b.	1,234	1,215	1,049	1,267	n.b.	n.b.	
Proctor Density	g/cm³	1,59	1,568	n.b.	1,622	1,605	n.b.	1,646	1,772	1,633	1,691	1,675	n.b.	
Optimum Water Content	% by mass	16,7	18,9	n.b.	18	19	n.b.	16,1	15,6	18,7	18,3	10,9	n.b.	
Particle Shape	% by mass	5,5	11,3	9,3	n.b.	15,4	17,3	7,6	9,6	20,8	14,6	12,3	13	max. 50
Resistance to Freezing and Thawing < 5 m	% by mass	9,2	6,4	12,9	8,9	6,7	11,3	3,6	4,4	2,9	3,5	4,3	2,3	max. 3(5)
< 0,71 mm	% by mass	4,6	1,9	7	4,7	4	4,4	1,7	2,8	1,1	1,8	1,7	1,4	max. 2,5
Resistance to Fragmentation	% by mass	35,1	37,3	35,7	38,9	37,6	36	38,1	38,4	40,6	37,5	34,1	29,1	max. 40

Table 4 Elution Datas (DEV-S4 Process) of Different MSWI Bottom Ashes														
Parameter	Unit	A	B	D	F	G	H	I	J	K	L	M	N	TL HMVA*
Calcium	mg/l	140	229,6	171,3	64,9	632,1	203	129,5	214,5	132,1	118,4	234,5	123,5	
Potassium	mg/l	89,7	39,7	40,4	40	71,6	497	19,4	74,8	49,9	37,8	60,5	49,9	
Sodium	mg/l	121	74,3	99,2	74,3	39,1	98,9	15,9	1	74,1	64,4	n.a.	38,8	
Chloride	mg/l	178	n.a.	81,4	n.a.	61,8	77,2	31	500,3	340,6	201,2	n.a.	130	250
Sulfate	mg/l	264	n.a.	471,1	n.a.	306,3	380	278,7	n.a.	214,4	289	n.a.	229,8	600
Chromium	mg/l	67,2	n.a.	38	91,1	150,2	n.a.	93,2	273,9	74	89,2	93,4	73,8	0,05
Nickel	mg/l	30,3	49,4	6	60,8	78,4	73,7	80,1	211,6	12,4	27,2	15,8	16,9	0,04
Copper	mg/l	169	139,4	44	153,3	327,8	167	162,3	17,2	44,4	409,1	32,8	204,9	0,3
Zinc	mg/l	103	178,9	34	129	154,2	112	189,9	n.a.	20,7	28,9	25,1	32,7	0,3
Arsenic	mg/l	n.a.	32,7	0,2	23,5	n.a.	n.a.	n.a.	n.a.	7,2	7,2	8,9	12,6	
Lead	mg/l	31,5	305,3	8	43,5	76,5	101	89,4	136	11,8	25,7	39,7	43,2	0,05
pH		11,1	12,1	11,5	11	11	11	9,3	10,9	11,1	11,4	n.a.	11,5	7 bis 13
el. Conductivity	mS/cm	162	376	130	130	98	118	71	136	193	177	n.a.	160	600

* Crucial Linmits: Technical Supply Terms for MSWI Bottom Ashes (TL HMVA-StB), 1995

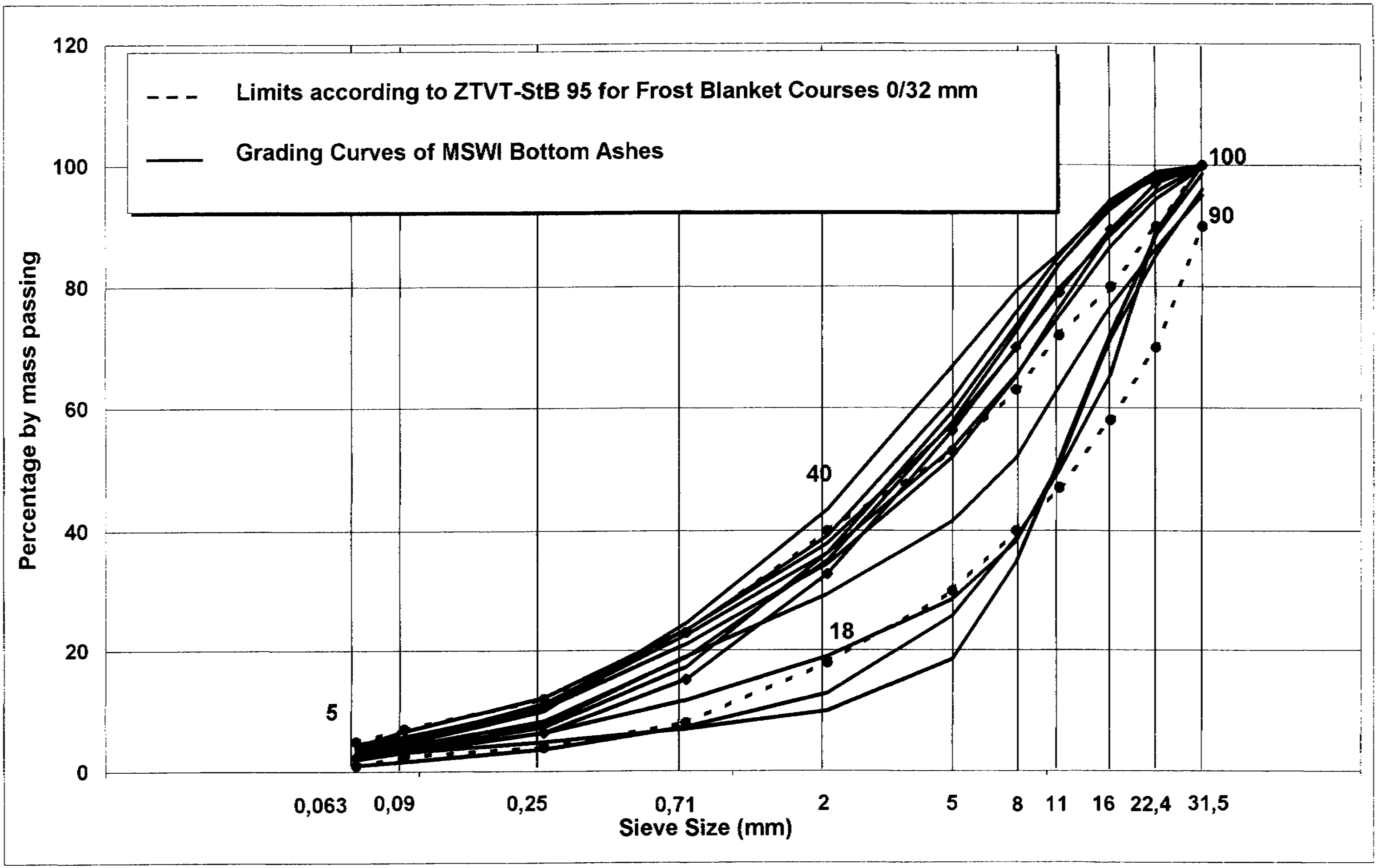

Fig 1: Grading Curves of MSWI Bottom Ashes

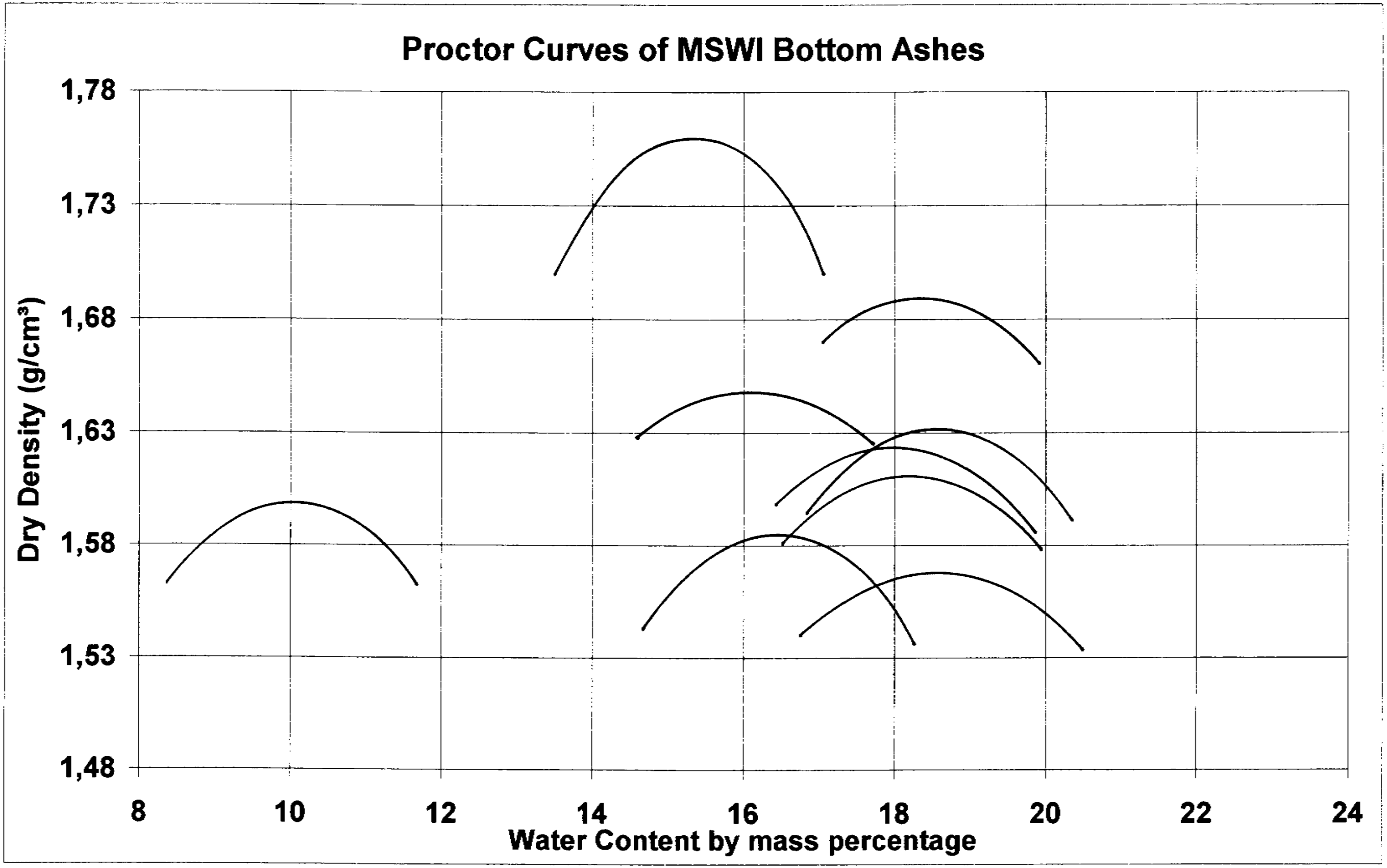

Fig. 2 Proctor Curves of MSWI Bottom Ashes