Introduction of CFD toward Recycling Technology of Incineration ash

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1. Introduction

In some developed countries, bottom ash is being reused for roadbase material, cover soil or limited purpose under the control of relevant guideline or regulation, but in Korea only a small portion of bottom ash has been recycled as a raw material for making the brick or the interlocking block. The reason of inactive recycling activity in Korea is mainly because Korean government has not enacted the relevant recycling guideline or regulation, and thus most of recycling activity on incineration residue has being done negatively due to leaching possibility of heavy metals.

The developed treatment technologies for bottom ash at home and abroad as follows ;

- **Melting treatment** is considered as a good way to detoxify the various inorganics and organics in bottom ash, including dioxins, but it shows some problems such as re-emission of volatile heavy metals, including Pb and Hg, and the requirement of high instrumental and running cost.
- **Cement solidification treatment** is considered to meet the current elution standards for landfill, but is also shows the leaching possibility of heavy metals and chloride and the decomposition inability of hazardous organics such as dioxins in bottom ash.
- **Chemical agent treatment** seems to have advantages of easy operation and cheap construction cost but it also shows the leaching possibility of chloride as well as the decomposition inability of dioxins.
- **Solvent extraction treatment** has a possibility of simultaneous removal of heavy metals and dioxins, but it requires a complicated facilities and lead to the hydrogen emission problem.
- **Aging treatment** seems to be the simplest and cheapest way among five technologies surveyed to stabilize the heavy metals in bottom ash, but treated bottom ash can be dissolved by acid rain and most of hazardous organics such as dioxins are not decomposed by this technology.
- Therefore, on the basis of our reference plants and experiment result, we suggest treatment technology for bottom ash recycling by **sintering** of Grate/Rotary kiln (G + R).

Bottom ashes from MSWI characterized by different combustion and bottom ash discharge technologies were tested for their leaching stability in the as - discharged state and after simple treatment procedures. The treatment included washing, **sintering** at 850℃ and 1,000℃, and melting at 1,300℃. Main conclusions drawn from these tests are : washing removes substantial portions of chlorides and other soluble components ; thermal treatment reduces the TOC substantially ; **sintering** at temperatures of 1,000℃ and even below improves the fixations of heavy metals ; melting causes further improvement, but the increase in stability is low compared to the energy consumption. On this basis recommendations can be made to improve the bottom ash quality by simple in-plant measures : modifying of the quench tank to establish simple washing and taking care for adequate sintering of the bed material at the end of the grate.

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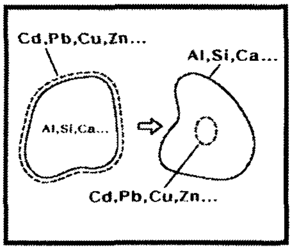
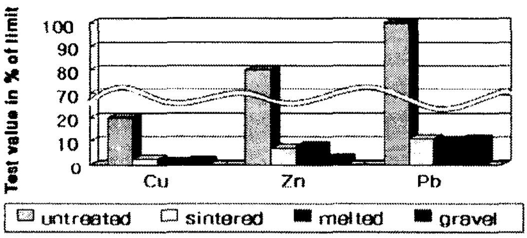


<Fig. 1 Reaction>

<Fig. 2 Structure of bottom ash before sintering>

<Fig. 3 Structure of bottom ash after sintering>

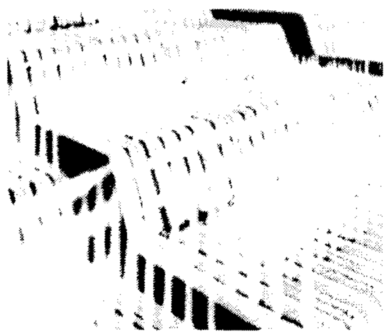
The question how to control a high bottom ash quality has been subject to laboratory scale experiments on ashes from full scale MSWI. The basic idea was to stabilize heavy metals by means of a **sintering** process. The physico- chemical treatment causes changes not only in porosity and density but also in the incorporation of metal ions into the silicate and oxide lattice of the matrix.



<Fig. 4 DEV S4 results of thermally treated bottom ashes and gravel (data standardized to the respective limits of the German LAGA memorandum for utilization)>

2. Good technology of "Halla" - Stoker Incinerator

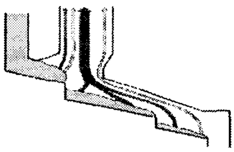
2.1 Grate photograph



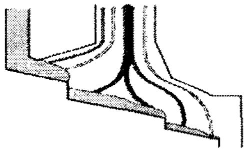
<Fig. 5 Primary air injection through grate>

- Minimization of Pressure loss of combustion air through grate
  - Saving motor power of air fan
  - Reducing fly ash on the refuse layer
- Heat-resistance design at high calorific value (15MJ/kg)
  - Low pressure = Large hole
  - Large hole = Good cooling effect of grate
  - Long life time = six(6)~ten(10) years

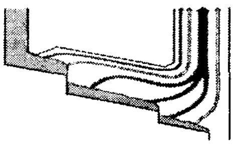
2.2 Various flow of furnace



<Fig. 6 Counter Flow>



<Fig. 7 Center Flow>



<Fig. 8 Parallel Flow>

2.3 Effect of radiation arch

<Fig. 9 Effect of radiation arch>

Radiation arch in the combustion chamber outlet

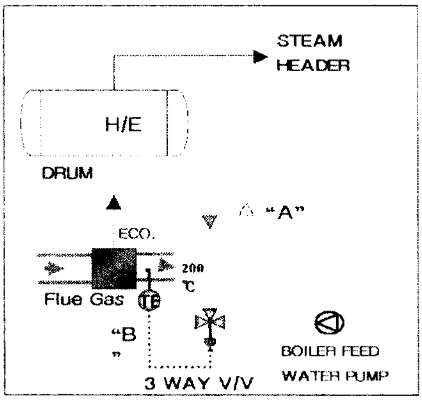
- Formation of strong swirling and depression of fly ash by two-way flow
- Effective drying of high moistured waste by radiation heat

2.4 Cooling air injection through furnace wall

<Fig. 10 Cooling air inject through furnace wall>

→ Restraint of clinker formation due to adhesion of inert substance on furnace wall

2.5 Flue gas temperature control at the boiler outlet by 3-way valve



<Fig. 11 Flue gas temperature control at the boiler outlet by 3-way valve>

- In case of low temperature of flue gas at economizer outlet
  : Mainly "A" direction of boiler feed water
- In case of high temperature of flue gas at economizer outlet
  : Mainly "B" direction of boiler feed water

2.6 Measured result of Dioxin

(unit : ng-TEQ/N㎥)

Owner of plant	Flue gas teratment	Emissi-on limit at stack	measured value	
			at boiler outlet	at stack
Changwon city(4yrs)	SNCR+SDR +AC+BF	0.1	0.849	0.0258
Pusan city	AC+EP +WS+SCR	0.1	2.27	0.012
Ulsan city	SDR+AC +BF+SCR	0.1		0.010
Mapo, Seoul city	SDR+AC+BF1 +BF2+SCR	0.01	(0.5)	(0.01)

3. Grate-Rotary kiln(G+R) technology

The grate / rotary kiln waste incineration technology was developed during the '70. The basic idea of the plant concept was that the waste is dried and pyrolysed and partially burned on the waste grate. The remaining fixed carbon was burned in the rotary kiln. In order to burn last carbon in the clinker, long residence times and high temperatures are required, which cannot be achieved on a grate. The clinker residence time inside the rotary kiln is in the order of 45 to 60 minutes. As there is not added under air in the rotary kiln, the combustion is only taking place on the surface of clinker in the rotary kiln. Compared to blowing through the fuel layer as on the waste grate, the burning rate is small. The clinker is heated from above by the passing flue gas and by the heat evolved by combustion of the clinker carbon.

The clinker in the rotary kiln should be heated till it reaches the softening temperature. By heating the clinker, low melting point metals and heavy metals and alkalis are evaporated from the clinker. Furthermore, the molecular diffusion speed is very high in near melt clinker, which means that a very homogeneous clinker is obtained. The softening mode of rotary kiln clinker operation gives the best clinker quality. However, operating the rotary kiln close to melting, demands accurate temperature control of the rotary kiln. The softening clinker mode operation generates equal quality of clinker.

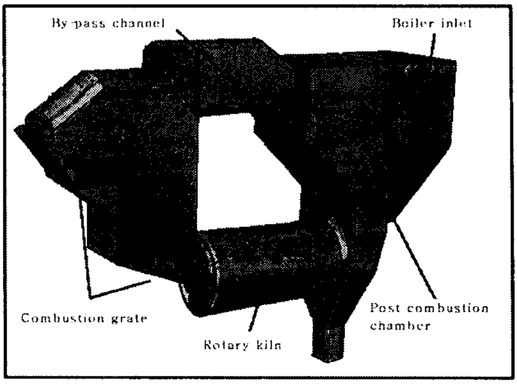
The basis of the design the 70'tees was an energy split of 60% in on the grate and 40% in the rotary kiln. However, practical experience showed that it was not possible burn a large fraction of the fixed carbon in the rotary kiln, as oxygen in that amount cannot be transported to the burning surface in the rotary kiln. Therefore, a much larger part of the combustion must take place on the grate. Estimations of the energy split between the grate and the rotary kiln indicates that between 80~90% of the energy is released upon the grate and only 10~20% of the energy is released in th rotary kiln. However, it is important that the clinker is not burned totally out before entering the rotary kiln, as a little content of carbon in the clinker is necessary for heating up the clinker and creating the reducing conditions inside the clinker necessary for producing Cr(Ⅲ).

As the heat value of the waste have risen through '90, the grate rotary kiln plants have experienced a number of operation problems. Due to the increased heating value, the furnace temperatures have gone significantly up.

The increased amount of pyrolysis and gasification products from the grate, has demanded changes in the secondary air system for better gas phase combustion.

As existing secondary air systems have proven insufficient for cooling away the heat at higher NCV's, water injection for cooling the furnace and rotary kiln has been installed.

3.1 Sintering Process

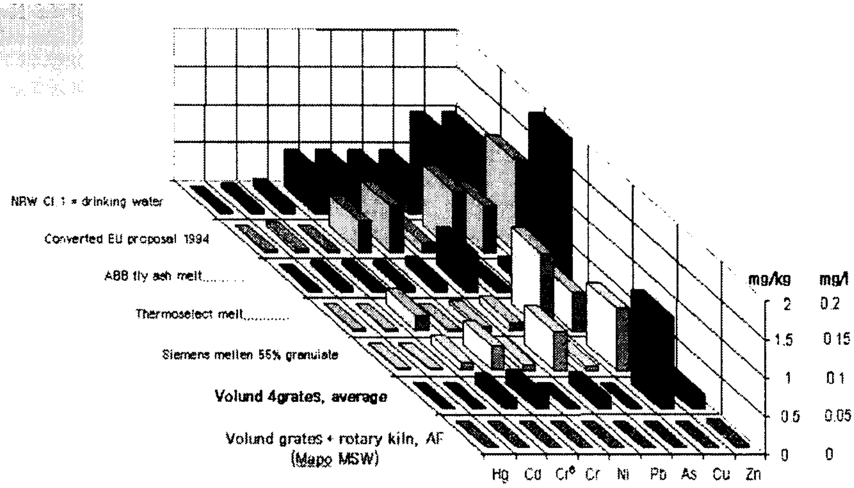


<Fig. 12 Sintering Process>

- 950℃~1,050℃ Operation for initial melting
- One hour resident time
- Slowly rotation for mixing(2~6 rph)
- Waste is the only fuel, no oil, gas, coal or electricity and no pure O_2 addition
- Significant improved slag quality as regards leaching of heavy metals.

3.2 Bottom ash quality

Leachate mg/l DEV-S4, L/S=10



Slag quality, Leachate mg/kg CEN accum, L/S=10									
	Hg	**Cd**	**Cr-6**	**Cr**	**Ni**	**Pb**	**As**	**Cu**	**Zn**
Volund grate +rotary kiln AF	0.003	0.0005	0.005	0.004	0.002	0.01	0.01	0.011	0.04
TL HMVA CL-1*1) (Mapo, Seoul)	0.01	0.05	-	0.5	0.4	0.5	-	3.0	3.0
TL HMVA CL-2*2) (Jeonju)	0.01	0.05	-	0.5	0.4	0.5	-	3.0	3.0
Siemens molten 55% granulate	0.005	0.02	0.1	0.31	0.08	0.5	0.05	0.8	0.38
Thermoselect melt	0.005	0.01	0.2	-	0.05	0.1	1.0	0.5	0.08
ABB fly ash melt	0.01	0.05	0.05	0.05	0.1	0.5	0.05	0.1	2.1
Converted EU proposal 1994	0.006	0.04	-	0.4	0.6	0.12	0.8	0.6	1.2
NRW cl.1 = drinking water	0.01	0.05	0.1	0.5	0.5	0.5	0.5	1.0	1.0

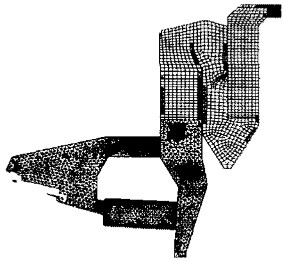
- Conductivity *1) 250 mS/m
  *2) 600 mS/m
- Cl *1) 30 mg/ℓ
  *2) 250 mg/ℓ

4. Present status for recycling of incineration ash

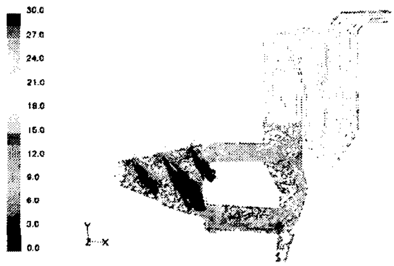
Nation	kind of ash	Usage	Amount	Rate	Treatment method	Quality requirement	Legal basis
Japan	Bottom ash	-Road filler -Road base -Interlocking block -Asphalt filler -Sand	22,800t/yr (1995)	17%	- Melting - Heat Treat + Separation + Washing		
	Fly ash (CaSO4)	Cement			Heat treat +Separation +Dewatering		
USA	Bottom ash	-Asphalt filler -Concrete block -Cement -Road filler -Road base	108,500 t/y (1998) 54,290 t/y (1994) 218,180 t/y (1990)	6~10%	-Use lime, phosphate -Ferrous and non ferrous metal separation -Size separation -Mix with natural material	-Size distribution -Physical property -Mix with natural material -Ferrous and non ferrous metal removal	-Federal law FHWA (AASHTO T27-84) -ASTM -ASME

Nation	kind of ash	Usage	Amount	Rate	Treatment method	Quality requirement	Legal basis
Netherlands	Bottom ash	-Road filler -Road base	690,000 t/y (1995)	More than 90%			Regulation for construction material (1995)
	Fly ash		16,000 t/y (1995)	20%			
Denmark	Bottom ash	-Parking area -Road base -Road filler	400,000 t/y	80~90 %	separation/ Screening	pH : 9~11 Alkalinity : 1.5eq/kg Pb : <300ppm Cd : <10ppm Hg : <0.5ppm Moisture : 17~25%	
Germany	Bottom ash	Road base		60%	Three months Aging	-Observance of leaching standard	LAGA TL-HMVA
France	Bottom ash	Architecture		45%	Aging	-Observance of leaching standard	AFNOR NF X31-210
	Fly ash	Architecture & civil			Melting	-TSS<5% -As<2mg/kg -Cd<1mg/kg	
Korea	Bottom	Brick Road base			Separation		Under legislation

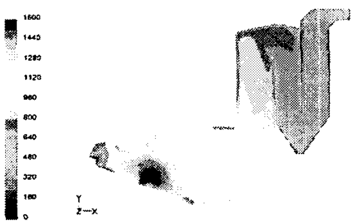
5. Materials of G+R



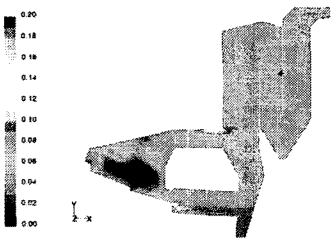
<Fig. 13 Surface mesh used in the CFD model.>



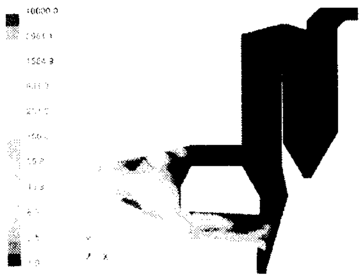
<Fig. 15 Velocities CFD>



<Fig. 14 Temperature CFD>



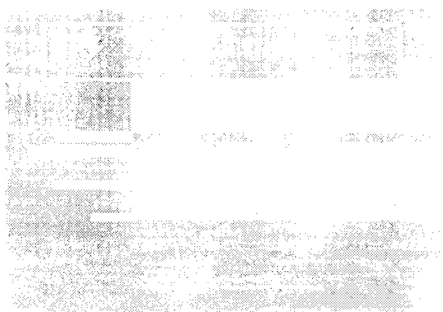
<Fig. 16 Oxygen CFD>



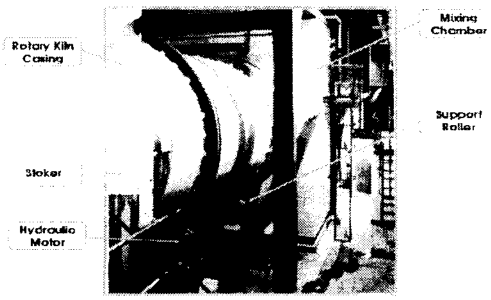
<Fig. 17 CO CFD>

Rotary kiln sintering

<Fig. 18 Flame view from R/K outlet>



<Fig 19. Road base material>



<Fig 20. Side view of G + R>

6. Reference List

6.1 G+R List (by BWV)

Nation	Unit	Nation	Unit	Nation	Unit
Argentina	4	Germany	2	Japan	50
Belgium	4	Hongkong	17	Russia	4
Denmark	23	India	2	Spain	1
France	9	Italia	2	Sweden	5

Nation	Unit	Nation	Unit
Suisse	2	USA	32
Taiwan	3	Korea	(3)
Turkey	1		
England	9	**Total**	**173**

6.2 Stoker(G) and G + R List (by Halla)

Name	Capacity	Type	Remark
Changwon city	200x2	Stoker	Completion +Operation
Ulsan city	200x2	Stoker	Completion +Operation
Pusan city	200x1	Stoker	Completion
Yongin city	100x2	Stoker	Under Constructing

Name	Capacity	Type	Remark
Miryang city	50x1	Stoker	Under Construction
Mapo, Seoul city	250x3	G+R	Under Construction
Inchun city	250x2	Stoker	Under Design
Ansung city	50x1	stoker	Under Design
Halla paper CO.	380x1	FBC	Completion