The Study of Bottom and Fly ash generated by the Melting system Incinerator using Electrolysis gas

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I. Introduction
Melting of residual incineration fly and bottom ash at high temperature (vitrification) can be lead to a volume reduction to one half or one third of the original amount [1], destruction of > 98% of dioxins, furans and other organic compounds [2], and also making the heavy metal unleachable [3]. Melting of residual ash at high temperature modify the state of ash and transformed it into a type of glass that is innocuous for the environment and a valuable source of secondary raw material with applications in construction and road building industries. The aim of this study is to stabilize the heavy metals in fly ash using energy efficient and environmental friendly electrolysis gas.

II. Experimental Methods
The fly and bottom ashes used in this study were collected from stoker type incinerator at Pyong-chon (Kyung-ki Province, Korea) operated by Dongbu Cooperation. Its capacity was 200 tonnes of MSW per day. In incinerator MSW was burned in combustion chamber at about 850 °C and flue gas was cooled through waste heat boiler and treated through spray dry absorber and bag filter. Thermal energy recovered from there was used to generate electricity and for district heating. MSWI ashes (bottom and fly) were melted at 1450 °C in ash melting furnace (E&E Company, Korea) shown schematically in Figure 1. The temperature of furnace is measured with two thermocouples inserted inside the furnace from the top. Ash melting furnace contains six electrolysis gas burners, of which four burners were used simultaneously during ash melting and two were kept as stand by. 35 cc of water glass (a mixture of sodium and potassium silicate) was added to 1kg of fly ash during melting to avoid flying of fly ash.

Figure 1. Schematics of ash-melting system using electrolysis gas
III. Results and Discussion

a) Composition of fly and bottom ashes

Fly and bottom ashes received from incinerator were gray in colour. Major components of bottom ash were SiO₂, CaO, Al₂O₃, Fe₂O₃, Na₂O, and MgO, whereas fly ash contains CaO, Na₂O, SiO₂, K₂O, and ZnO. Distribution of various components in fly and bottom ash depends on their relative volatility. More volatile components (CaO, ZnO, K₂O) are enriched in fly ash while less volatile compounds (SiO₂, Al₂O₃, Fe₂O₃, MgO) remain in bottom ash. Distribution of heavy metals also follows the same principle. As fly ash contains a higher fraction of more volatile Pb, As, and Cd, bottom ash is enriched with Cr and Cu. These results are also consistent with the work reported in literature [1, 4-6]. Ratio of alkaline CaO to acidic SiO₂ is known as basicity of these ashes. Basicity of bottom ash is 0.55 due to the large amount of silica and that of fly ash is 18.016 as it contains high CaO content.

b) Effect of Basicity

Basicity of pure fly ash and pure bottom ash were 18.016 and 0.55 and addition of 3.5% (v/w) of water glass to fly ash to make it palleted during melting changes its basicity to 2.949 due to the increase in its silica content to 13.7 wt. %. Palletized fly ash and bottom ash were then melted separately in an ash melting furnace at 1450 ºC for vitrification. Vitrified fly ash was dark gray in colour with a rough surface and appears to be a poor vitrified product [5]. On the other hand, bottom ash slag was very dark brown in colour with a glassy surface [7]. It was reported in the literature that CaO acts as a stabilizing agent and SiO₂ as a glass former [6, 8] and amorphous or crystalline nature of slag depends on the mass ratio of the CaO/SiO₂ (i.e., basicity) of slag. Thus, fly ash contains little silica, its melting does not lead to glassy material and glassy nature of vitrified bottom ash is due to the presence of a large amount of silica (38.7 wt %) and low basicity of slag [5, 7]. Therefore, effect of basicity was further examined by addition of bottom ash in different ratios to palleted fly ash (FA: BA = 1:1, 1:2, 1:4) during melting in furnace. It was found that vitrified products were having a good glassy surface and dark brown in color. This dark brown color may be due to the higher SiO₂ content and decrease of basicity of mixture of fly and bottom ashes [5, 7]. Basicity of ash mixtures for 1:1, 1:2 and 1:4 (FA: BA) were 0.858, 0.782 and 0.729, respectively. It was also reported in the literature that lower basicity (0.24-1.24) leads to a more amorphous glassy matrix during the melting of MSWI ashes [5].

c) Morphology of ashes and their slag

Better glassy surface and amorphous nature of slags obtained from vitrification of bottom ash and their mixtures with fly ash were further confirmed from SEM photos of ashes and their slag shown in Figure 2. In fly ash many agglomerates are present (Figure 2(a)) and bottom ash particles are needled. Also particle size distributions in fly ash are more uniform than bottom ash. Vitrified fly ash has a highly dense elongated porous structure and a smooth glassy surface is observed in SEM of all the slags containing
bottom ash.

Figure 2. SEM photographs of MSWI ashes and their slag ($\times$1500)

IV. Conclusion
Silica content of bottom ash (37.8 wt %) was much larger than fly ash (2.47 wt %) and CaO content in fly ash (44.5 wt %) is more than that bottom ash (20.79 wt %). Basicity (CaO/SiO$_2$) of fly ash and bottom ash were 18.016 and 0.55. Vitrification of palletized fly ash and its mixture with bottom ash at 1450°C were successfully carried out, for the first time, using energy efficient electrolysis gas. Effect of basicity was studied by addition of bottom ash to fly ash in different ratio during vitrification. Water glass was added to fly ash to make it palletized. Basicity of palletized fly ash slag decreased (18.016-2.949) due to addition of 3.5% (v/w) of water glass. It was found that vitrification decreased the leachable concentration of hazardous heavy metals to much below the Korean regulatory limit value. SEM results also revealed that melted slags of bottom ash and mixed ash were having smooth glassy surface. Glassy vitrified slag of mixed ash and pure bottom ash were found to be non hazardous according to Korean standard and may have the potential to be used as road building and construction material in future.

V. Reference