Properties of Ceramic Produced from Clay and MSW Incineration Bottom Ash Mixtures

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Abstract

The bottom ash, by-product from municipal solid waste (MSW) incineration process, incurs high cost for its disposal. The aim of the present work is to study the feasibility of reuse of the bottom ash in clay ceramic production in order to introduce an alternative way to manage this waste. In this study, batch compositions were prepared by adding of 0-50 wt% of the bottom ash from domestic incinerator plant in Thailand into the clay. The properties of the samples after sintering at 1075-1125°C such as bulk density, water absorption and flexural strength were determined. A leaching test of the selected sample was also done. The results showed that the clay with high amount of bottom ash had good physical and mechanical properties. The low water absorption of less than 0.5% and highest flexural strength of 75 MPa were obtained for the clay with 30 wt% bottom ash sintered at 1125 °C. These results suggested that it is possible to reuse MSW incineration bottom ash as a raw material for producing clay ceramics.

Keywords: MSW incineration bottom ash, ceramic, clay, properties, leaching test

1. Introduction

The increase of municipal solid wastes (MSW) has become a major problem in several countries, including Thailand. An attractive method for this waste management is incineration because it can reduce the volume of waste by about 90%. However, the incineration process still leaves a large amount of solid residues i.e., bottom ash and fly ash which require high disposal cost.

For solving environmental problems of waste disposal, reuse of waste in the production of ceramic materials is a good solution for a wide range of solid wastes, including incineration ashes [1-5]. Some researches on the MSW incineration ashes have shown that the ash can be used in several types of ceramic materials such as brick, cement, cement-based products, glass and glass-ceramic [5-12].

In the present work, mixtures of the clay with various amounts of bottom ash addition (0- 50 wt %) were prepared to study the feasibility of reuse of the bottom ash in clay ceramic production. The physical, mechanical and chemical properties of the obtained ceramic were examined.

2. Experimental

2.1 Raw Materials

Raw materials used in this study were a traditional clay mixture and the bottom ash from municipal solid wastes (MSW) incineration plants located in Lamphun, a province in the northern part of Thailand. Table 1 shows their chemical compositions analyzed by X-ray fluorescence.

The as-received ashes were sieved to particle sizes less than 1 mm prior to their further use.

2.2 Sample Preparation

The clay (0 wt% bottom ash) and the clay with 10 wt% - 50 wt% of bottom ash were prepared by mixing in a conventional ball mill for 18 hrs. Subsequently, the slurries were dried and sieved through 100 mesh. These mixed powders were uniaxially pressed into test bars (6×7×40 mm^3) under a load of 7 MPa. The green compacts were sintered in a high temperature electric furnace at three temperatures, 1075, 1100 and 1125°C, for 30 min.

Table 1 Chemical compositions (wt%) of the raw materials

Oxide	Compositions (wt%)	
	Bottom ash	Clay
SiO_2	11.32	67.56
Al_2O_3	6.00	25.91
CaO	31.61	0.76
Fe_2O_3	3.66	1.20
Na_2O	5.76	0.68
K_2O	6.10	2.77
MgO	1.89	0.48
TiO_2	2.43	0.37
SO_3	14.98	0.24
P_2O_5	2.29	-
ZnO	1.09	-

2.3 Characterization of the samples

The sintered samples were tested for density, water absorption and room temperature flexural strength. The density and water absorption were determined by using the Archimedes' method according to ASTM C373-88 [13]. The four-point bending flexural strength was measured with a universal testing machine (Instron model, 55R4502), using a constant cross-head speed of 0.5 mm/min.

The leachability characteristic of heavy metals was performed following toxicity characteristic leaching procedure (TCLP) method 1311 [14]. Their leached out concentration was then analyzed by using atomic absorption spectrometry (AAS).

3. Results and Discussions

3.1 Bulk density and water absorption

Fig.1 shows the bulk density of the samples sintered at three temperatures. The density of the clay slightly decreased with small amounts of the bottom ash addition (10-20 wt%). When the amount of bottom ash was higher, the density showed an increasing trend. The maximum densities for the samples with 40, 50 wt% bottom ash were 2.45 g/cm^3, 2.48 g/cm^3 at 1100°C and 2.42 g/cm^3 for the sample with 30wt% bottom ash at 1125°C, respectively.

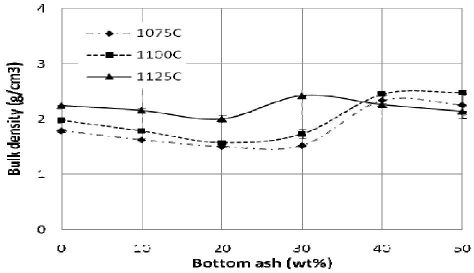

Fig. 1 Bulk density of the sintered samples

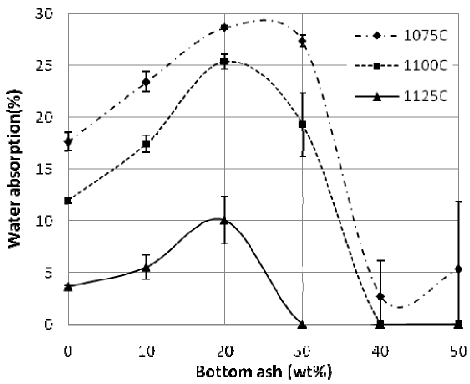

Fig. 2: Water absorption of the samples sintered at three temperatures

Water absorptions of the samples sintered at 1075, 1100 and 1125°C are shown in Fig.2. It was noticed that the water absorption of the samples decreased with an increase in sintering temperature at any given amount of bottom ash. This behavior was also observed for the clay without any bottom ash addition.

At each sintering temperature, the water absorption of the samples changed with the bottom ash addition. The water absorption increased with increasing amount of the bottom ash up to 20 wt% and it decreased rapidly when higher amounts of bottom ash (30-50 wt %) were added. This result suggested that the addition of a high amount of bottom ash reduced the open porosity of the clay.

The water absorption of 0.5% and less was achieved for the samples with 30-50 wt% bottom ash after sintering at high temperature (1100-1125°C).

According to ISO 13006, the water absorption of the low water absorption dry-pressed ceramic tile is ≤ 0.5 % [15]. The water absorption of the samples with high amount of bottom ash (30-50 wt%) sintered at 1100°C and 1125°C met this requirement. Therefore, these samples were selected for examination in further experiments.

3.2 Flexural strength

Fig. 3 shows the flexural strength of the selected samples. It can be observed that the flexural strength of the samples related to their density. The flexural strength of the sample with 30 wt% bottom ash increased with increasing sintering temperature. By contrast, the strength of the samples with 40 and 50 wt% bottom ash dropped after being sintered at 1100°C and above. This resulted from the overfiring of the sample. The strengths of 75, 70 and 66 MPa were obtained for the sample with 30 wt% bottom ash sintered at 1125°C, the sample with 40 wt% and 50 wt% bottom ash sintered at 1100°C, respectively. These values were higher than the minimum limit of 35 MPa for ceramic tiles which is indicated in ISO standard [15].

The above results revealed that MSW incineration bottom ash is a waste that can be reused as a raw material for making clay ceramic products such as floor tile and pavement tile.

3.3 Leaching of toxic element

Though the bottom ash is classified as non-hazardous waste [6-7], some environmentally risky elements such as cadmium (Cd), arsenic (As) and lead (Pb) were found in its composition [16]. Therefore, it is important to investigate the leachability characteristic of such elements in order to assure their safety for real application.

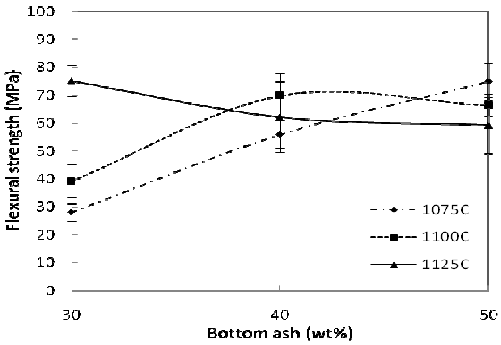

Fig. 3 Flexural strength of the selected samples

The result of the leaching test of the sample with 30wt% bottom ash sintered at 1125°C is given in Table 2 together with the US regulatory limit (US EPA (40 CER 261)) [14].

Table 2 Leached out concentration of heavy metals in the sample

Elements	Concentration (ppm)	US EPA limit (ppm)
Zn	0.392	500*
Pb	< 0.3	5
Cd	< 0.1	1
Cr	< 0.3	5
As	< 0.02	5

* ref. [12]

The sample exhibited very low leached out concentration. Comparing with the regulation, the sample is satisfactory for application.

4. Conclusion

The bottom ash from municipal solid wastes (MSW) incineration plant was added to a traditional clay mixture. It can be concluded from the results that:

- The addition of high amount of bottom ash reduced the open porosity of the clay.
- The clay with high amount of bottom ash addition sintered in the temperature range of 1100-1125°C resulted in the water absorption of ≤ 0.5 %.
- High flexural strength of 70-75 MPa was obtained for the clay with 30 and 40 wt% bottom ash additions.
- The product had good physical and mechanical properties which complied with the standard.
- Therefore, the bottom ash can be re-used as a raw material in the clay ceramic production.

5. Acknowledgement

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6. References

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