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Characteristics of municipal solid waste incineration fly ash with cement solidification treatment

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A B S T R A C T

Cement solidification technology can effectively reduce environmental pollution caused by municipal solid waste incineration (MSWI) fly ash. The present study aimed at investigating the impacts of three factors on the heavy metal leaching content, and the curing time on the strength of mortar specimens blended with MSWI fly ash. The factors are the quantity of cement, the PH value of leaching liquid and the vibrating leaching time. And the fly ash used in experiments is sampled from Harbin MSWI power plant. The results demonstrated that the leaching concentration of heavy metal of MSWI fly ash reduced significantly after being blended with cement, especially for Pb and Cd. As the PH value of the leaching liquid increased, the heavy metal leaching concentration quickly cut down to a very low value. The heavy-metal leaching concentration significantly increased with leaching vibrating time in range of 16 h or 32 h. But conversely, both flexural strength and compressive strength of mortar specimens obviously dropped and the curing time of mortar specimens was delayed due to the addition of MSWI fly ash. Fortunately, the strength of mortar exceeds strength requirement of non-main building and base structure concrete and it can be recycled as base structure material.

1. Introduction

The MSWI technology has many significant advantages including volume reduction, weight reduction, fast processing speed and heat energy recycling. And it has been widely used all over the world [17,21,30,32,41]. However, the MSWI fly ash contains a large amount of toxic heavy metal materials, such as mercury, plumbum, cadmium, chromium, cuprum, zinc and so on, and highly toxic substances such as dioxin. Some of them go into the environment again, pollute ground water, soil and air, and cause secondary pollution under the action of acid rain [33,35]. Xiaohong Feng et al. collected rain and snow samples in eight places that located down the wind and presented semicircle radial distribution in the (2–15) km intra-field around the incinerator in Claremont New Hampshire [13]. It turned out that incinerator made heavy metal pollution increase about 20% in the air of the study field around. Beitou MSWI plant and Shenzhen MSWI plant both used MSWI fly ash to do leaching test. And the results were that concentrations of Zn, Pb, Cu, Cr and Cd in the leaching liquid obviously exceeded solid waste leaching toxicity identification standards [18,22]. Standards for pollution control on the MSWI issued by China have clearly regarded fly ash as the hazardous waste. Therefore, proper treatment processes should be required for fly ash and ensure final form of MSWI fly ash harmless [7].

At present, the treatment methods of waste incineration fly ash include: (1) taking appropriate treatments and landfilling as dangers. However, overall cost of the method is higher, so few of cities and incineration plants can afford the cost [1]; (2) solidification and stabilization; (3) separating heavy metals and fly ash, and respective resourceful treatments [4,19,34,39]. Among them, curing and stabilization treatment technology is one of the international main methods at present. And also cement is the most widely used hazardous waste stabilizer in the developed countries such as Europe and the United States in recent years. Hence, USEPA has regarded cement solidification technology as the best technology of hazardous waste treatment. Researches have showed that the hydration reaction activity of MSWI fly ash is rather low. Mixing fly ash would delay the cement hydration process in some degrees and when fly ash was added to a large dosage, it can significantly reduce the cement mortar strength. Mangialardi's research found that despite doing pretreatment process of washing and

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crushing et al., it was difficult for building blocks to meet higher strength [24]. Macakova did fly ash stabilization experiments with the cement which was produced by residue of Mg smelting process [23]. The results proved that although the strength of blocks did not higher after above process, the leaching toxicity of heavy metals in fly ash fitted the index of USEPA [16]. However it indeed has a good effect that cement stabilizes and solidifies MSWI fly ash. Yuan Ling et al. did an experiment that researched cement blending with MSWI fly ash and mineral admixtures [36]. They found that it not only improved the mechanical property of solidified body, but also was very beneficial to solidify heavy metals, that displayed composite gel effect is in the macro level. Li Zhuoran discussed the impact of clay mineral on Pb in fly ash (Li et al., 1999). They considered that zeolite nonmetallic minerals could solidify heavy metal Pb in fly ash. Heavy metals in fly ash would go into the structure of hydration products by containing, replacing and absorbing, and then it makes heavy metal leaching concentration reduction obviously.

MSWI fly ash has a mass of soluble salt such as chlorides and sulphates except heavy metals and those soluble salts could also leach into environment. However, the chlorides and sulphates have a limit when fly ash is treated. In response to the problem, the removal of chlorides and sulphates can be carried out by means of a proper waste washing pre-treatment. And the process has been previously researched by many researchers [6,15,25,29,37]. Mangialardi found a four-stage washing process to be able to convert the original MSWI fly ash into a material with improved characteristics [26].

The above results explained the effect of cement solidifying MSWI fly ash, including beneficial and harmful effects. But they all did not give the overall and systemic studies. Based on this, the paper researched the method of cement solidification fly ash process in depth and then further investigated the important roles and benefits of cement solidification process on controlling heavy metal leaching toxicity of MSWI fly ash. The fly ash sample comes from Harbin MSWI power plant. Selecting cement as binder of MSWI fly ash, series experiments were done to investigate the influence of some parameters on the impacts of stabilization fly ash. In detail, the impacts contained cement mixing ratio, curing time and PH value of leaching liquid. And of course, for improving the property of MSWI fly ash, the water washing pre-treatment process is very necessary before the cement solidification and leaching test. This study will provide experiment data about ash-cement mass proportion, PH value, leaching time of heavy metals and compound strengths. Meanwhile it will be a reference in this field.

2. Materials and methods

2.1. Materials

2.1.1. Sample selection

The MSWI fly ash sample came from Harbin MSWI power plant. Firstly, under the condition of incinerator steady operating, the previous fly ash was completely cleared. Then 20 kg fly ash were taken and made uniform after the ash in the bag dust collector reaching a certain quantity. Eventually it was dried with 24 h (105 °C) to reach constant weight as a sample.

2.1.2. Sample physico-chemical property

100 g MSWI fly ash were selected to be used as sample. After being dried, the percentage contents of main chemical components were determined with X-Ray Diffraction (type: XPert Powder; made in Netherlands). And other physical performances of fly ash also were measured with corresponding instrument. The determination results are shown in Table 1. From the test results, it can be seen that the main components in incineration fly ash are CaO, SiO_2, AlO_3 and Fe_2O_3, and the main components are great close to those supplementary cementitious materials commonly used at present, such as blast furnace slag and fly ash. The physical performances of fly ash reflect that it has a lower specific surface area and pore volume so that it probably owns a poor physical creativity. Table 2 reports the particle size distribution of MSWI fly ash. As shown in Table 2, contents of >154 μm and <30 μm are respectively 9.12% and 7.85%, and the size with maximum proportion is 54–74 μm. Therefore, the average size range of fly ash should be 54–74 μm.

2.1.3. Cement

Cement used in the experiments was the “Xiaoling” brand 32.5 ordinary Portland cement which was produced in Harbin swan cement LTD. Table 3 shows the physical and chemical properties of “Xiaoling” brand 32.5 ordinary Portland cement used in the experiments. Similarly, the main components of cement are also CaO, SiO_2, AlO_3 and Fe_2O_3.

2.1.4. Aggregates

According to GB 178-1997 Standard sand for cement strength test, proper sand was prepared to be used in the experiments. Particle size of the standard sand is shown in Table 4. The cumulative content of passing a 0.25 size sieve is more than 95%. The silicon oxide content in standard sand is greater than 96.0%. In addition, the percentage of loss on ignition (LOI) of sand is less than 0.4% and sediment percentage is less than 0.2%.

2.2. Methods

2.2.1. Heavy metal contents of fly ash

Firstly, 100 g samples were weighed for degradation with HNO_3–HF–$HClO_4$ method. Metals in the fly ash would translate into ions state existing in degradation liquid [20]. Then contents of heavy metal in the digestion solution could be analyzed using ICP-MS (the device was

Table 1
The main components and physical performance of fly ash sample.

Component							Physical performance			
SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	Cl^-	Moisture content (%)	Density (kg/m^3)	Specific surface area (m^2/g)	Pore volume (cm^3/g)
27.51	5.11	7.12	23.25	3.13	12.23	11.5	0.6–2.0	2580	5.28	0.022

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