Characterization and thermal treatment application for radioactive concrete wastes from nuclear power plant decommissioning

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1. Introduction

The treatment and disposal of contaminated concrete waste is a major issue for decommissioning projects of nuclear power plant (NPP) due to the very huge volume and large quantities of wastes generated [1]. Most of the intermediate and low level solid radioactive wastes generated during the NPP decommissioning process are concrete and metal used as building materials, which account for more than 70% of total solid waste [2]. The amount of produced waste from NPP decommissioning will be well above the total amount of waste generated during the NPP operation. Therefore, there is a great need for technologies to reduce and treat concrete waste generated. The purposes of this study are to characterize the concrete wastes, investigate the dehydration process, and optimize the thermal treatment for Co and Cs spiked concrete samples at various temperatures to reduce the volume of dismantled radioactive solid wastes.

2. Materials and Methods

2.1 Concrete preparations

Concrete coupons were prepared using Portland cement (Type I/II) with dry ingredients such as sand, fly ash, and crushed rock and water at the ratio of 0.21, 0.37, 0.05, 0.24, and 0.13 in a single batch. Figure 1 shows mixing procedure for the synthetic concrete waste sample [3]. A hand mixer was used with the mixing process including loading period, mixing period, and discharging period (Figure 1). The loading period divides the two parts: dry mixing for 5 minutes and wet mixing for 5 minutes. Dry mixing is the mixing of dry ingredients before water is added. Wet mixing is the mixing of slurry after water is added. The duration of this period depends on how long and fast the dry ingredients are mixed well before and after the addition of water. After mixing period, the concrete slurry was poured into a paper mold (5cm in diameter and 10cm in height) and cured in the desiccator under the constant moisture content (80-100 % RH) for 5days. To make concrete samples contaminated by Co and Cs, 0.4 mL (10ppm) of their solutions were individually spiked at a depth of 0.7 cm using a glass syringe during the curing. Initial mass of the samples after curing is about 98g.

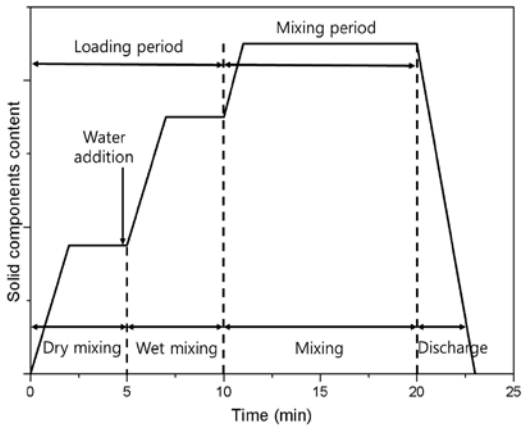

Fig. 1. Mixing procedure for preparing concrete coupons.

2.2 Thermal treatment

Thermal treatment experiments were carried out with various temperature such as 105°C, 200°C, 300°C, 400°C, 500°C, and 600°C for an hour in the furnace. After thermal treatment, these samples were cooled at room temperature and were crushed by rubber hammer. Finally, the crushed concrete samples were sieved and particles size less than 1mm in diameter were used to separate cement paste specimen from the aggregates in the concrete.

2.3 Characterizations

To investigate the effects of thermal treatment at different temperatures, the collected cement paste and concrete aggregate were characterized by Scanning Electron Microscope (SEM)/Energy Dispersive Spectrometer (EDS) for surface morphology and chemical composition, X-Ray Diffraction (XRD) for mineral identification, Fourier transformed-infrared (FT-IR) for the changes of chemical binding, and X-ray fluorescence (XRF) for the bulk chemical composition as well as total Co and Cs contents. To quantify the total concentrations of Co and Cs in the final concrete samples, Inductively coupled plasma atomic emission spectroscopy (ICP-AES) was used after digestion.

3. Results and Discussions

The preparation of concrete samples was optimized by the mixing procedure as shown in Figure 1. XRD shows that major minerals are quartz (SiO_2), portlandite

($Ca(OH)_2$), and calcite ($CaCO_3$). The mass loss of the concrete samples with increasing temperature and FT-IR results at different temperature are shown in Table 1 and Figure 2, respectively. During the thermal treatment, Co and Cs spiked samples started to lose the mass with increasing temperature from 105°C to 600°C. It means that about 95% of the contained water in initial concrete sample was evaporated above 300°C condition from sorbed water. In addition, portlandite vibrations at 3640cm^{-1} decreases with increasing temperature and disappears above 600°C (See the red box in Figure 2). Calcite vibrations are shown at 1412 cm^{-1} and it seems to decrease above 600°C [4].

Table 1: Mass loss with various temperature

Temperature (°C)	Mass loss (%)	
	Co concrete	Cs concrete
105	9.4	9.9
200	11.2	11.0
300	11.7	11.8
400	12.6	12.6
500	13.0	13.3
600	13.4	14.0

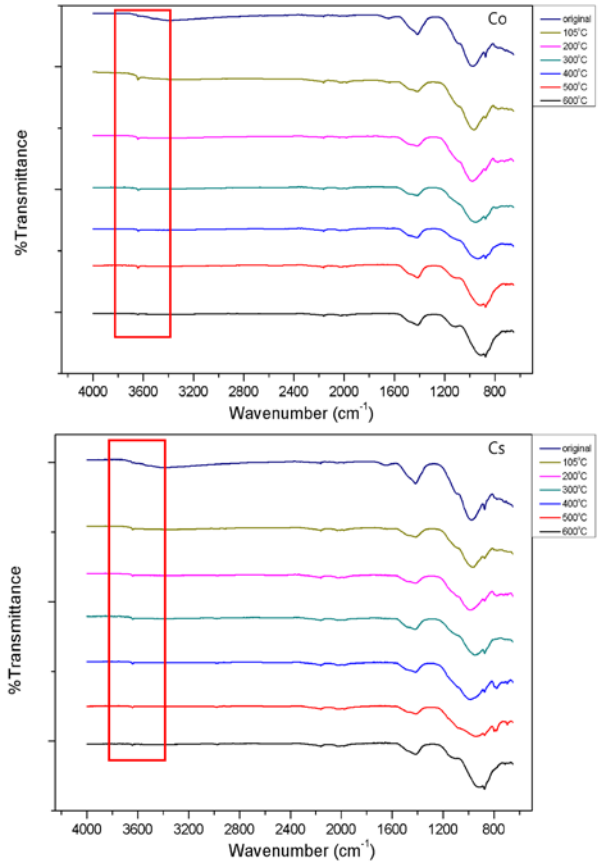

Fig. 2. FT-IR results for Co (top) and Cs (bottom) spiked samples after thermal degradation with different temperature.

In other words, CO_2 gas can be released from calcite, which was formed above 400°C from portlandite reacting with atmospheric air [5]. Regardless of the kind of spiked solutions, all FT-IR data show similar results. Finally, after thermal treatment at 600°C, the 50wt% cement paste of total concrete mass can be easily separated from the aggregate.

4. Conclusions

This study investigated the synthetic contaminated concrete samples by Co and Cs, and optimized thermal treatment method to reduce the waste volume. After thermal treatment at 600°C for an hour, the cement paste was separated from concrete aggregates. These results provide the possibility and optimum condition of thermal treatment to reduce the volume of concrete wastes.

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