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Technical note

The characterization of cement waste form for final disposal of decommissioning concrete wastes

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ABSTRACT

In Korea, the decontamination and decommissioning of KRR-1, 2 at KAERI have been under way. The decommissioning of the KRR-2 was finished completely by 2011, whereas the decommissioning of KRR-1 is currently underway. A large quantity of slightly contaminated concrete waste has been generated from the decommissioning projects. The concrete wastes, 83ea of 200 L drums, and 41ea of 4 m^3 containers, were generated in the decommissioning projects. The conditioning of concrete waste is needed for final disposal. Concrete waste is conditioned as follows: mortar using coarse and fine aggregates is filled with a void space after concrete rubble pre-placement into 200 L drums. Thus, this research developed an optimizing mixing ratio of concrete waste, water, and cement, and evaluated the characteristics of a cement waste form to meet the requirements specified in the disposal site specific waste acceptance criteria. The results obtained from a compressive strength test, leaching test, and thermal cycling test of cement waste forms conclude that the concrete waste, water, and cement have been suggested as an optimized mixing ratio of 75:15:10. In addition, the compressive strength of the cement waste form was satisfied, including a fine powder up to a maximum of 40 wt% in concrete debris waste of about 75%. According to the scale-up test, the mixing ratio of concrete waste, water, and cement is 75:10:15, which meets the satisfied compressive strength because of an increase in the particle size in the waste.

1. Introduction

Korea research reactors (whereafter KRR, KRR-1 and KRR-2) were shut down in 1995, and the decommissioning project for the KRRs was started in 1997 (Lee et al., 2010). During the decommissioning project for the KRRs, a large amount of radioactive waste such as combustible, non-combustible waste, metal, and concrete was generated. The concrete waste accounted for nearly 80% of the total decommissioning waste. The concrete wastes from the decommissioning of the KRR-2 and auxiliary facilities were stored in about 800 drums (200 L), and the concrete waste in sludge form from saw cutting on concrete blocks was also stored in powder type after drying in a dryer. Such wastes were temporally stored in the KRR-2 reactor hall and will be transferred after construction to a permanent disposal site. The bulk size concrete wastes were preplaced in drums for transportation, disposal integrity, and volume reduction. The internal empty space of 200 L drum was filled with dispersed and particulate matters which are needed to theirs fixation, watering and cementing. According to the dispersion waste transfer regulation of Korea, waste containing a particulate material is to be packaged such that the non-dispersion material. In other words, the dispersion waste must be fixation when the particle diameter of less than 0.01 mm is composed of more than 1% or less than 0.2 mm is composed of more than 15% of the waste weight

The fixation and solidification methods of the radioactive wastes are generally cement, asphalt, glass, and polymer solidification methods. Among these methods, the concrete solidification method is the most popular because of low cost and well-known technology (IAEA, 2007). A cement waste form of lab-scale (D 5 cm × H 10 cm, D 15 cm × H 30 cm) was made to evaluate the waste acceptance criteria of the permanently disposal site.

In this paper, cement waste form was made by using the concrete wastes such as debris concrete waste, powder concrete waste generated from KRRs. The water and cement ratios that affect the physical and chemical properties of the cement waste form. A high penetration and leaching phenomenon were generated, but the water and cement ratios do not fit because the void fractions grow and play a role as a passage. In addition, if the mortar is too watery, the water remaining at the hydration reaction is evaporated and is directly attributable to the generation of the porosity. The porosity also gives rise to strength decrease, shrinkage and cracking. Therefore, the optimized mixing ratio at the lab-scale is very meaningful.

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The manufactured cement waste form is evaluated on the basis of the satisfaction regarding the compression strength, leaching safety, and heat resistance of the waste acceptance criteria for the disposal of radioactive wastes. There are studies on the decommissioning concrete waste recycling and disposal at a general facility today continue to be vigorous, but studies on radioactive concrete waste are not vigorous based on their characteristic. This paper will be usefully as a view of management for decommissioning concrete waste.

2. Experimental

2.1. Material

Heavy and light concrete were produced at decommissioning of the KRRs. The activity concentration of dump concrete waste used in the experiment is below 0.2 Bq/g, and the activity concentration of the fine particulate concrete wastes of a sludge types is above 0.2 Bq/g. The density of dump concrete waste and fine concrete waste were 3.18 g/mL and 1.13 g/mL, respectively. The clean cement used in the experiment for making cement waste form is Portland cement.

Fig. 1 shown the size distribution of concrete waste, and fine particle concrete waste generated from decommissioning work. To homogeneously mix the composition, the used concrete is passed through a standard sieve of 4.75 mm. However, in case of a scale-up experiment, the concrete waste evenly applies a size of 50 mm (15%), more than 4.75 mm (37.4%), more than 1 mm (24.9%), and less than 1 mm (22.7%) considering the mold size and particle size distribution. When the radiation dose was analyzed using a low energy gamma-ray spectrometer, the Co-60 of dump concrete waste was 0.02 Bq/g. In case of fine particulate concrete waste, Co-60 and Cs-137, were 0.82 Bq/g and 0.11 Bq/g, respectively.

2.2. Making cement waster form

The cement waste form is made of concrete waste of less than D = 4.75 mm. The weight percent of concrete waste, water, and cement varied such as the mixing ratio by 50–80%, 10–30% and 5–35%, respectively, to find the optimal mixing ratio of mortar. In case of fine particle concrete, the weight percent of the concrete waste versus fine particle concrete varied by 10–40%. The mixing method was performed based on the Korea Standard (KS L 5109). The solidified mold used was a PE circular mold (D 5 cm × H 10 cm) and was tramped using a tamping bar (D 3.5 cm × H 3.5 cm × L 17 cm, S1-582) after the mold was 1/3 filled with mortar, and the empty space was again filled with mortar. In addition, the mortar was cured for 28 days after sealing the top using vinyl. The free water was occurred at 1 day, 1 week, and 2 weeks after hardening because the free water caused the drum corrosion at the disposal site.

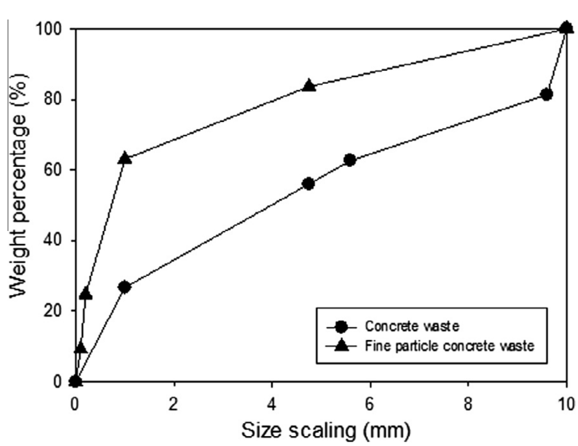

Fig. 1. The size distributions of concrete and fine particle concrete waste for cementation experiment.

2.3. Physicochemical analysis of decommissioning concrete waste

For characterization of the concrete waste, the pH and content of the water were measured in accordance with the Korean Ministry of Environment's official waste test method (Official waste test method, 2007) and the physicochemical analysis was performed by SEM–EDS (Scanning Electron Microscope/Energy Dispersive X-ray Spectrometer, JSM-6300) and XRD (X-ray Diffraction, D5000). In addition, a chemical analysis was performed using ICP-AES (Inductively Coupled Plasma Atomic Emission Spectroscopy, ULTIMA-2C) and AAS (Atomic Absorption Spectrometer, Analyst 400). Before the analysis, the sample was pre-treated in a mixed-solution of 10 mL HNO_3, 4 mL HCl, and 0.25 mL HF.

2.4. Compression strength evaluation of cement waste form

The compression strength of cement waste form was determined by a measurement using Korea Standard F2405. The sample produced using the bulk of the mold (D 5 cm × H 10 cm) was measured to apply force of 5 ± 2%/min at the automatic concrete compression strength apparatus (FS-1050A). The scale-up experiment was performed to choose the mixing ratio of the compression strength measured value, 3.44 Mpa, as the LLIW Acceptance Criteria. Fig. 2 shows the concrete and mold (D 15 cm × H 30 cm) used at this time. The concrete waste was fixed at a weight ratio of 75%, and the water and cement ratios were adjusted to 15:10 and 10:15. The size of cement waste form is D 5 cm × H 10, and the strength was measured to apply a force of 5 ± 2%/min at the hydraulic using concrete compression strength measuring instrument (J1-303).

For a water-proof evaluation of the cement waste form, the leachate experiment was performed using the ANS 16.1 method (RWTF-TP-07, 2008). The radioactivity of the concrete waste using a solidification experiment is 6.17 Bq/g. The sample of the ratio of diameter/height = 1 should be used according to the experiment method; the fabricated cement solidified was cut using a cutting machine (CMV-2000) into a D 5 cm × H 5 cm size. After cutting, to remove the fine particles, the leachate experiment sample was cleaned using distilled water and ethanol and dried for 1 h in 110 °C. The leachate water was put into a plastic container to maintain the ratio of the leachate water volume (V_L), and the solidification surface (S) is 10 ± 2 cm. The leachate water was sampled at intervals of 0.08(2 h), and 0.3(7 h), and 1, 2, 3, 4, 5, 19, 47, and

Fig. 2. Image of concrete rubble (D > 50 mm) and mold (D 15 cm × H 30 cm) for scale-up test.