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Original Article

Characteristics of Cement Solidification of Metal Hydroxide Waste

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A B S T R A C T

To perform the permanent disposal of metal hydroxide waste from electro-kinetic decontamination, it is necessary to secure the technology for its solidification. The integrity tests on the fabricated solidification should also meet the criteria of the Korea Radioactive Waste Agency. We carried out the solidification of metal hydroxide waste using cement solidification. The integrity tests such as the compressive strength, immersion, leach, and irradiation tests on the fabricated cement solidifications were performed. It was also confirmed that these requirements of the criteria of Korea Radioactive Waste Agency on these cement solidifications were met. The microstructures of all the cement solidifications were analyzed and discussed.

1. Introduction

A lot of uranium contaminated soil and concrete waste is generated from the dismantlement of uranium conversion facilities [1]. There are several disposal methods for radioactive waste such as regulation exemption, decontamination, and long-term storage [2]. It is necessary for us to achieve permanent disposal of radioactive waste. The methods for solidifying radioactive waste include cement solidification, asphalt solidification, and polymer solidification [3]. Cement solidification has several advantages such as well-known materials and technologies, various applications, and reasonable cost. On the contrary, it has certain disadvantages such as a large volume expansion of solidification for radioactive waste. Because cement solidification has excellent structural strength and a shielding effect, it is widely used for the permanent disposal of radioactive waste [3]. Cement solidification operates as a barrier against the leach of nuclides during radioactive waste disposal. To evaluate the criteria of Korea Radioactive Waste Agency (KORAD), integrity tests on the solidification of radioactive waste needs to be performed [4].

In this study, to inspect the criteria of KORAD, we carried out cement solidification of the metal hydroxide from

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radioactive waste. An integrity inspection such as the compressive strength, immersion, and leach tests on cement solidification were performed. We also analyzed the experimental results according to the criteria of KORAD. The calculation of the leachability index on the cement solidification (C-2.0) and cement solidification (C-1.5) for the leach detection of nuclides was carried out. The integrity of the cement solidification (C-2.0) and cement solidification (C-1.5) was also evaluated.

2. Materials and methods

2.1. Cement solidification

For the disposal of metal hydroxide in radioactive waste, we applied a cement solidification method [5–8]. The cement solidification was carried out according to the ratio of metal hydroxide from radioactive waste to cement. To mix the cement, water, and metal hydroxide powders, we used a mortar mixer according to the manual procedure. The equipment used for measuring the compressive strength of the cement solidification was also applied.

The ratio of metal hydroxide from radioactive waste to cement for cement solidification (C-2.0) was 2.0. At first, the powders were made from metal hydroxide waste using a bowl and a rod. Secondly, cement and water were mixed using a mortar mixer, and then the powders were added into the mortar mixer and mixed uniformly. Thirdly, the homogeneously mixed material was put into four polyethylene molds and then entirely covered with vinyl. Fourthly, after 4 weeks of cement solidification, a visual inspection of the cement solidifications was performed and it was then cut into 50-mm diameter and 100-mm height sections using a microcutter. The volume expansion of the primary cement solidification was about 150% in comparison with the volume of metal hydroxide from radioactive waste. Table 1 shows the chemical analysis of metal hydroxide waste, which consists of aluminum, potassium, calcium, iron, magnesium, sodium, uranium, etc. Table 2 shows the conditions of the cement solidification. The unit weight of the cement solidification decreases as the ratio of waste to cement increases.

The ratio of metal hydroxide from radioactive waste to cement for the cement solidification (C-1.5) was 1.5. The cement solidification (C-1.5) was made using an aluminum mold. Good solidification, such as primary cement solidification, was achieved. The volume expansion of cement solidification (C-1.5) was about 165% in comparison with the volume of metal hydroxide from radioactive waste. The ratio of metal hydroxide from radioactive waste to cement for the cement solidification (C-2.5) was 2.5. The third cement solidification was also made using an aluminum mold. After 1 week of cement solidification, a visual inspection of the cement solidification was performed, and all the cement solidifications were then fractured. It was determined that the ratio of metal hydroxide from radioactive waste to cement for cement solidification should be under 2.0.

Table 1 – Chemical analysis of metal hydroxide waste.

Element	wt%	Element	wt%	Element	μg/g
Al	21.0	U	0.87	Sr	177
K	6.86	Si	0.57	Li	275
Ca	6.66	Mn	0.24	Ni	177
Fe	5.60	Cu	0.10	Nd	164
Mg	2.33	Zn	0.10	Th	91
Na	1.62			Y	69

Al, aluminum; Ca, calcium; Cu, copper; Fe, iron; K, potassium; Li, lithium; Mg, magnesium; Mn, manganese; Na, sodium; Nd, neodymium; Ni, nickel; Si, silicon; Th, thorium; U, uranium; wt, weight; Y, yttrium; Zn, zinc.

2.2. Integrity tests on cement solidification

The integrity tests on cement solidification consisted of compressive strength, immersion, and leach tests. The compressive strength of the cement solidification was measured using compressive strength equipment (HCT-DC50 (Heungjin Company Model No.: HCT-DC50 Gimpo, Republic of Korea); Fig. 1). An immersion test was performed using the electric conductivity measurements and pH measurement of immersion water from the immersion exchange time (1 day, 3 days, 7 days, 14 days, 37 days, and 90 days). After an immersion test of 90 days, the compressive strength of the cement solidification was determined. The process of the leach test is as follows.

At first, the initial concentration of uranium on cement solidification was measured. The cement solidification is immersed in demineralized water for 90 days. Samplings of the demineralized water from the cumulative immersion time (2 hours, 7 hours, 1 day, 2 days, 3 days, 4 days, 5 days, 19 days, 47 days, and 90 days) were made, and a chemical analysis of these samplings was carried out. Finally, the leachability index was calculated with the initial concentration of uranium, uranium concentration owing to the cumulative immersion time, the effective diffusivity, the volume of the specimen, the geometric surface area of the specimen, and the leach time.

$$L = \frac{1}{n}\sum_{1}^{n}[\log(1/D)]_n \quad (1)$$

$$D = \pi\left[\frac{a_n/A_0}{(\Delta t)_n}\right]^2\left[\frac{V}{S}\right]^2 T \quad (2)$$

$$T = \left[\frac{1}{2}\left(\sqrt{t_n}+\sqrt{t_{n-1}}\right)\right]^2 \quad (3)$$

Where L, leachability index; D, effective diffusivity (㎠/s); T, leach time representing the "mean time" of the leach intervals (s); a_n, radioactivity during exchange time of immersion water (Bq or Ci); A_o, initial radiation rate of the specimen (Bq or Ci); S, geometric surface area of the specimen (㎠); V, volume of the specimen (㎤); and △t, exchange time of immersion water (s).

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