Development of Cement Form an Enhancement for Leaching Resistance

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1. Introduction

Currently, the Korea Atomic Energy Research Institute (KAERI) is planning to build the Ki-Jang Research Reactor (KJRR) in Ki-Jang, Busan. One of the efficient way to treat radioactive waste is cement solidification. Thus, this study was focused on the development of cement for an enhancement of cesium leaching resistance. We used zeolite to improve the cesium leaching resistance of KJRR cement containing KJRR simulated liquid waste. We confirmed that zeolite successfully isolates KJRR cement based on an SEM-EDS spectrum analysis. A leaching test was carried out using KJRR simulated liquid waste containing 3000 mg / L of cesium for 90 days. Zeolite showed that KJRR cement made cesium leaching resistance 27.9% higher than the control value.

2. Methods and Results

2.1 Materials

Portland cement and zeolite were purchased from SSangyong, Zeobuilder. NaCl and Na_2SO_4 were purchased from Sigma-Aldrich (Mo, USA). All other chemicals used are of analytical or research grade.

2.2 Component of KJRR simulated liquid waste

The KJRR (Ki-Jang Research Reactor) simulated liquid waste constituents are as follows: NaCl 64.28 g L^{-1}, Na_2SO_4 106.53 g L^{-1}, and Cs^+ 3000 mg L^{-1} [1].

2.3 Manufacture of KJRR cement

The KJRR cement (including KJRR simulated liquid waste) were manufactured in accordance with the Korean Industrial Standard (KS-L-5109) [2]. The mechanical mixer was purchased from Jl-206 (Jeil Precision, Korea). KJRR cement was made to find the optimal mixing rate (W/C, where W is water and C is cement) from 0.45 to 1.30. In addition, we added zeolite to improve the cesium leaching resistance of KJRR cement (S/C S; zeolite, C; cement) from 1, 5, and 10 wt.%. KJRR cement solidified while curing at room temperature with relative humidity of 40 to 60 % for 28 days (Fig. 1). After 28 days, the uniformity of the surface of the KJRR cement was visually confirmed.

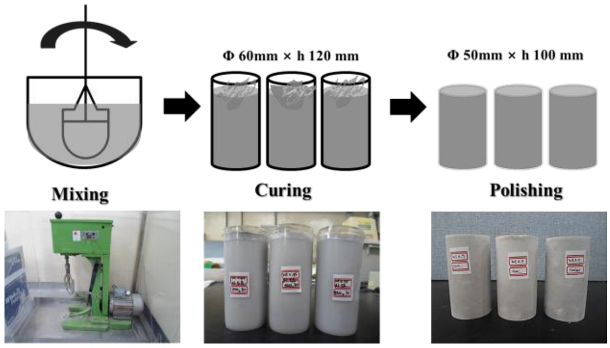

Fig. 1. Schematic diagram showing manufacture of KJRR cement.

2.4 Characterization of KJRR cement

The component of KJRR cement was analyzed using SEM-EDS. As shown in Table 1, it can be seen that (Na, Al, Si, Ca) ions, which are the main components of zeolite, increase with the zeolite content of KJRR cement.

Table 1. Component of zeolite and KJRR cement form

Element	Zeolite	KJRR (Without Zeolite)	KJRR (Zeolite 5%)	KJRR (Zeolite 10%)
	Weight (%)	Weight (%)	Weight (%)	Weight (%)
C	7.90	2.83	3.55	4.16
O	42.34	42.19	42.26	45.75
Na	15.48	2.60	4.81	5.86
Al	17.27	1.57	2.13	3.95
Si	16.80	6.50	7.49	9.50

2.5 Leaching test of KJRR cement

The Cumulative fraction leach (CFL) of cesium according to the change of zeolite content was calculated using the ANS 16.1 test method from USA. The leaching resistance was determined by considering the degree of cesium ions leached during the leaching test, and the cumulative fraction leach was defined as the equation below [3]

$$CFL = \frac{\sum A_i}{A_0}$$

$\boldsymbol{A_i}$= Cumulative leaching amount of material A during the leaching interval
$\boldsymbol{A_0}$= Initial content (g) of the material A.

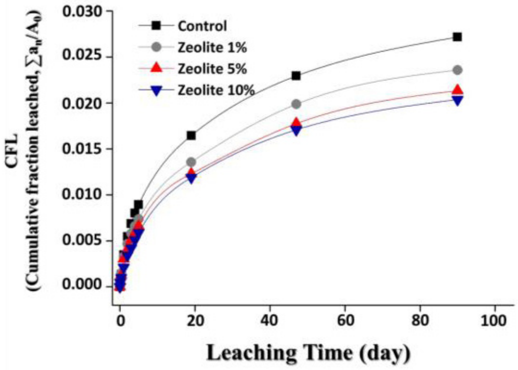

Fig. 2. Cumulative fraction of Cs^+ leached in zeolite KJRR cement.

It was confirmed that KJRR cement containing zeolite was less Cs^+ leaching than the control sample(KJRR cement, without zeolite) (Fig. 2). In addition, the leachability index can be obtained through by the following equation.

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

D_e= Effective diffusion coefficient ($cm^2\ s^{-1}$)
V= Volume of KJRR cement (cm^3)
S= Surface area of KJRR cement (cm^2)
T= n leaching time, which means the average time of the n th leach.

The leachability index (Li) was determined from the effective diffusion coefficient obtained from the above equation using the following equation.

$$L_i = -\log D_e$$

L_i= Leachability index

As shows in Table 2, it was confirmed that the leaching index was larger than 6, which means the leaching test meets the satisfied acceptance criteria for the final disposal facility. In addition, it was observed that the KJRR cement containing zeolite showed a cesium leaching resistance 27.9% higher than the control.

Table 2. Cesium Leachability index and leaching resistance of zeolite KJRR cement

Component	Leachability index of Cesium	Leaching resistance of Cesium (%)
Control	9.26	-
Zeolite 1%	9.40	12.6
Zeolite 5%	9.49	21.5
Zeolite 10%	9.52	27.9

2.6 Compressive strength test of KJRR cement

Table 3 shows the compressive strength results of the KJRR cement and zeolite KJRR cement. All experiment groups were satisfied with the final disposal facility.

Table 3. Compressive strength test of KJRR cement and zeolite KJRR cement

Compressive strength (Mpa)*		
Component	Number	Results
Control	1	27.60
	2	26.80
	3	25.30
Zeolite 1%	1	21.50
	2	20.80
	3	20.90
Zeolite 5%	1	24.80
	2	36.20
	3	30.50
Zeolite 10%	1	25.20
	2	24.10
	3	26.20

* Compressive strength acceptance criteria ≥ 3.45 MPa [3]

3. Conclusions

In this study, we made a KJRR cement with KJRR simulated liquid waste. In addition, we used zeolite to improve the cesium leaching resistance of KJRR cement. We demonstrated that zeolite successfully isolated the KJRR cement based on an SEM-EDS spectrum analysis. A leaching test was carried out using simulated KJRR liquid waste containing 3000 mg / L of cesium. Zeolite KJRR cement achieved a cesium leaching resistance 27.9% higher than the control value. In addition, all experimental groups were satisfied with the final disposal facility, such as the compressive strength and leaching test.

REFERENCES

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