Ceramicrete Solidification of Concrete Wastes From Nuclear Power Plants Decommissioning

Jae-Young Pyo* and Jong Heo

Pohang University of Science and Technology, 77, Cheongam-ro, Nam-gu, Pohang-si, Gyeongsangbuk-do, Republic of Korea

*vywodud@postech.ac.kr

1. Introduction

Large amount of radioactive concrete wastes are generated during the decommissioning of nuclear power plants. Most of the radionuclides are easily separated from the aggregates and enter mainly into the cement pastes during the heating and grinding process [1]. Powdered wastes composed of cement pastes and sand of less than 1 mm in diameter are generated. The objectives of this study are to solidify these powdered wastes generated from the concrete decontamination process using ceramicrete. The ceramicrete is formed by the acid-base reaction of calcined MgO and KH_2PO_4 in aqueous solution; $MgO+KH_2PO_4+5H_2O \rightarrow MgKPO_4{\cdot}6H_2O$. The superplasticizer (SP) is added to the starting mixtures to improve the flowability.

2. Experimental Procedures

Concrete wastes were formulated following the composition of the concretes used for nuclear power plants constructed by the Korea Hydro & Nuclear Power Co., Ltd [2]. The simulated concretes were heated at 350°C for 3 hr and was pulverized into powder and sieved to 1 mm. The formulations of ceramicretes are shown in Table 1. The molar ratio of MgO : KH_2PO_4 : H_2O was selected as 1.5 : 1 : 5 based on the preliminary tests. Additional waster was necessary in the specimens with no SP addition due to the increase of viscosity with the addition of wastes. 1wt.% of boric acid was added to retard the acid-base reaction of MgO and KH_2PO_4 that normally occurs quickly [3]. X-ray diffraction (XRD) patterns were recorded to analyze the formation of the ceramicrete. Compressive strengths were measured using a universal testing machine with specimens 20 mm in diameter and 40 mm in length.

Table 1. Compositions of ceramicretes prepared (wt%)

	W0	W25	W50	W25S	W50S
M/P*			1.5		
W/P**	5.00	5.23	10.78	5.00	5.00
MgO	21.05	15.57	7.72	15.58	10.31
KH_2PO_4	47.38	35.04	17.39	35.06	23.22
H_3BO_3	0.21	0.16	0.08	0.16	0.10
H_2O	31.36	24.24	24.81	23.21	15.37
Waste	0	25.00	50.00	25.00	50.00
SP	0	0	0	1.00	1.00
Total	100	100	100	100	100

*M/P is the molar ratio of MgO to KH_2PO_4.

**W/P is the molar ratio of H_2O to KH_2PO_4.

3. Results and Discussion

The compressive strengths of ceramicrete specimens decreased as the amount of wastes in the mixtures increased (Fig. 1). For example, when SP was not added, 28-days strength decreased from 33.25 to 7.61 MPa as waste loading increased from zero to 50wt.%. On the other hand, the addition of SP resulted in a large increase of the compressive strengths from 7.61 to 28.78 MPa for ceramicretes containing 50wt.% wastes. The high fluidity of the mixtures reduce the pore volume and makes result in the compact ceramicretes.

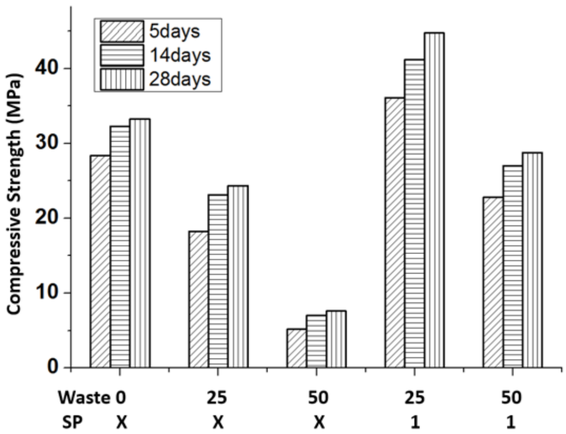

Fig. 1. The compressive strengths of ceramicrete.

The concrete wastes are usually composed of cement pastes and sands therefore, the crystalline phases are mostly calcium silicates and quartz. XRD patterns of ceramicretes containing simulated concrete wastes have peaks related to the $MgKPO_4 \cdot 6H_2O$ phases together with the residual MgO and waste components (Fig. 2).

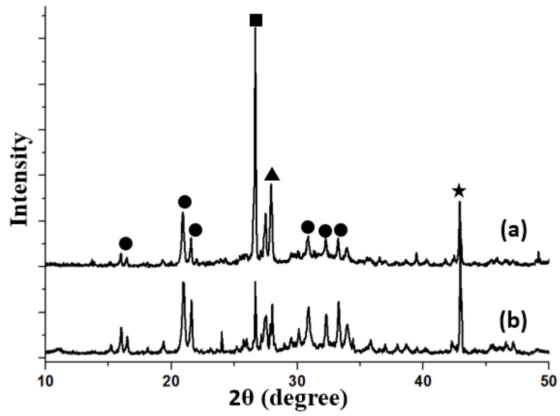

Fig. 2. XRD patterns of the ceramicrete specimens. (a) W50S and (b) W25S; circles: $MgKPO_4 \cdot 6H_2O$, stars: MgO, squares: SiO_2, triangles: Ca_3SiO_5.

4. Conclusion

Ceramicretes were developed to solidify the powdered wastes from decontamination of radioactive concretes. Addition of waste decreased the compressive strengths due to the increase of the viscosity. Small amount of superplasticizer (~1.0wt.%) improved the compressive strengths from 7.61 to 28.78 MPa. Formation of the ceramicrete $MgKPO_4 \cdot 6H_2O$ phase was clearly identified even when 50wt.% of the wastes were added.

ACKNOWLEDGEMENT

This work was supported by the National Research Foundation (NRF) grant funded by the Ministry of Science & ICT (NRF-2017M2B2B1072405).

REFERENCES

[1] B. Min, W. Choi and K. Lee, "Separation of clean aggregates from contaminated concrete waste by thermal and mechanical treatment", ANN. NUCL. ENERGY, 37, 16-21 (2010).

[2] J. Kim, D. Kim, S. Kang and J. Lee, "Influence of sand to coarse aggregate ratio on the interfacial bond strength of steel fibers in concrete for nuclear power plant", NUCL. ENG. DES. 252, 1-10 (2012).

[3] A.S. Wagh, Chemically Bonded Phosphate Ceramics. Elsevier, New York (2004).