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Effect of Emulsified Waste Cooking Oil on Durability Improvement of High-Volume SCMs Concrete

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Abstract. This paper presents evaluation results of the dosage of emulsified refined cooking oil (ERCO) on the improving durability performance of high volume supplementary cementitious materials (SCMs) concrete such as carbonation, chloride penetration, and sulfate attack resistance. The replaced SCMs were 30 % of fly ash and 60 % of blast furnace slag, and water-to-binder ratio 0.50 concrete mixture was prepared. The dosages of ERCO was changed from 0.25% to 1.0% to evaluate the influence of the ERCO dosages. The test results indicated that calcium salt of fatty acid created by the saponification of ERCO filled pores. Because of this pore-filling effect due to the reactions of ERCO in concrete matrix, the durability of hardened concrete was likely improved in a decrease of the carbonation depth and increase a resistance to chloride penetration and sulfate attack.

Keywords: emulsified refined cooking oil, durability, carbonation, fly ash, blast furnace slag

1 Introduction

The concrete industry is contributing to mitigating environmental contamination by using industrial by-products including fly ash and ground granulated blast-furnace slag (GGBS) as a means to reduce CO_2 emissions by replacing cement. As a result, the usage of the concrete mixture with various SCMS is on the rise. [1-3] From the former research [1], the authors observed that filling pores of the concrete with fatty acid created by chemical reaction of ERCO in concrete mixture with Calcium hydroxide ($Ca(OH)_2$). Based on this mechanisms of filling pores of concrete microstructure, durability related with outer environmental factors is expected to be improved with less permeability for normal strength concrete. [4, 5] Therefore, using the effect of decreasing permeability with ERCO in concrete mixture, further

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durability issues such as chloride invasion resistance, and sulfate resistance were examined.

2 Experimental Plan

The design of experiment in this study is shown in Table 1. For binder, based on the control mixture with no SCMs replacement, two different conditions of SCMs were prepared: 30 % of fly ash replacement by weight of cement, and 60 % of slag replacement by weight of cement. ERCO was replaced to the mixing water by weight of binder from 0.25 to 1.0 %. The properties of emulsified refined cooking oil (ERCO) are shown in Table 2.

Table 1. Experimental plan

Test factors			Levels	
Mix Proportions	W/B (%)		1	50
	Target slump (mm)		1	180 ± 25
	Target air contents (%)		1	4.5 ± 1.0
	Supplement materials (%)	OPC[1)]	1	100
		OPC : BS[2)]	1	40 : 60
		OPC : FA[3)]	1	70 : 30
	ERCO dosages (%)		4	0, 0.25, 0.5, 1
Tests	Hardened concrete		3	Accelerated carbonation Resistance to chloride attack Resistance to sulfate attack

1) Ordinary Portland cement 2) Blast furnace slag powder 3) Fly ash

Table 2. Physical properties of emulsified waste cooking oil

Admixture	Density (g/cm^3)	Main component (%)			Viscosity (cP)
		Saturated acid	Multi-Unsaturated acid	Simple saturation	
ERCO	0.98	15	54	23	25

3 Results and Discussions

3.1 Carbonation resistance with ERCO dosages

Figure 1 provides the influence of the ERCO dosage and SCMs on the carbonation depth of concrete depending on ages. For different SCMs, the carbonation depth was increased with BS and FA in concrete mixtures. However, as increase the dosage of ERCO, the carbonation depth was decreased; therefore, in 13-week, the concrete with 1.00% of ERCO showed approximately 2.5 – 3 mm lower carbonation depth than the concrete without ERCO treatment. Based on this improved performance of carbonation resistance, the decreased permeability against CO_2 was considered. This reduced CO2 penetration appears to be attributable to the same influence as observed in the test on resistance to chloride penetration.

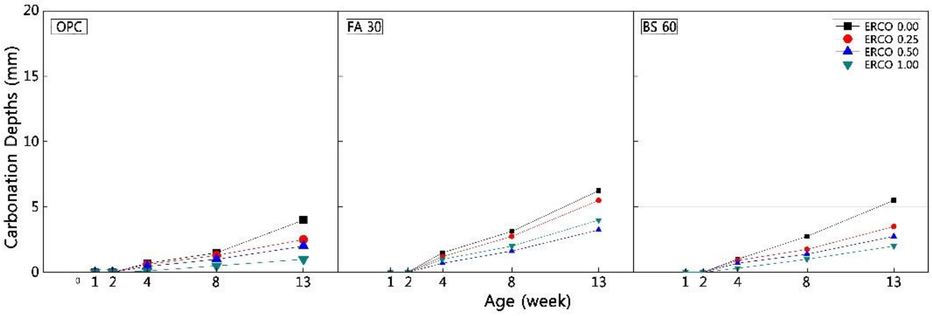

Fig. 1. Carbonation depth of the concretes with age depending on different admixtures and ERCO dosages

3.2 Resistance to chloride penetration depending on ERCO dosages

Figure 2 presents the effect of ERCO dosage with different SCMs on chloride penetration of concrete depending on ages. Depending on different SCMs, BS showed lower chloride penetration depth than other two cases. For different ERCO dosages, the penetration depth was observed to significantly decrease with increasing ERCO dosages from the early age of one week, compared to the sample without ERCO. This is due to blockage of chloride penetration by the filling the capillary pores of hardened concrete with the calcium salts of fatty acids created by the chemical reaction between the fatty acid, main component of ERCO, and calcium hydroxide.

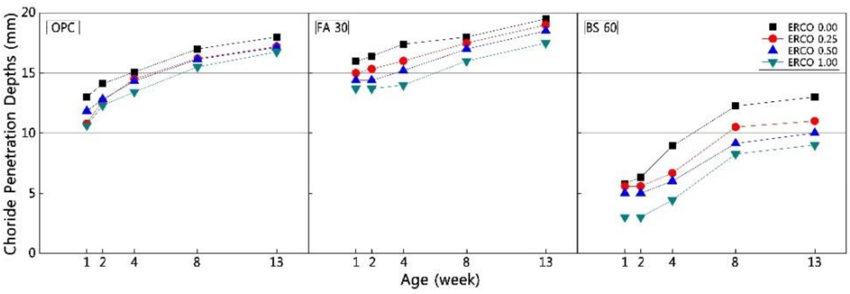

Fig. 2. Resistance to chloride penetration with age depending on ERCO dosages

3.3 Resistance to sulfate attack depending on ERCO dosages

The influence of ERCO dosage and different SCMs on the degree of sulfate attack on concrete depending on age was shown in Figure 3. Overall, the influence of the type of SCMs was found to be insignificant in OPC, BS, and FA, and the varied ERCO dosages showed limited influence on or a slight contribution to lowering the sulfate penetration resistance.

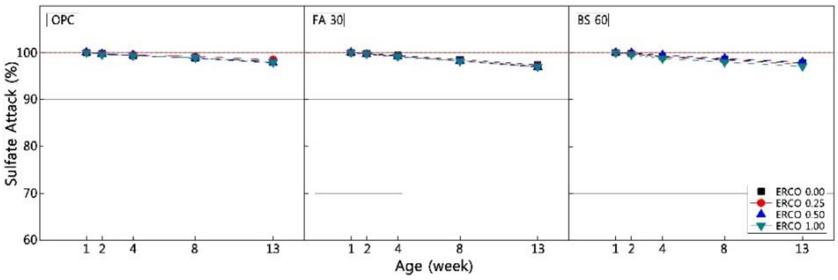

Fig. 3. Resistance to sulfate attack with age depending on ERCO dosages

4 Conclusion

In this paper, a various durability tests including resistance to carbonation, sulfate attack and chloride penetration of high-volume SCMs concrete depending on ERCO dosages was conducted. From the durability tests, it was found that calcium slats of fatty acids created by the saponification of ERCO filled pores in the concrete matrix and thereby enhanced the durability of hardened concrete. A quantitative analysis was conducted for concrete samples and revealed decreased depth of carbonation and increased resistance to chloride and sulfate penetration. These results demonstrate that the use of ERCO contributes to pore filling of the concrete.

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