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Durability of cementitious and geopolymer coating mortars against sulfuric acid attack.

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ABSTRACT: Successive deterioration in concrete structures which is caused by the acid attack, has increased the need for substantial and costly repairs to deal with the destruction of concrete structures. Common devastation of water transfer tunnels is due to sulfuric acid attack. One of the ways of maintenance of such structures is to perform the protective coating of the cementitious and geopolymer coating mortars, in which the different features of this coating layer should be studied. In this study, the mechanical properties and durability of geopolymer and cementitious coating mortars containing granulated blast furnace slag and natural pozzolan have been compared. Five cementitious mortar mixtures were prepared with water to binder ratio of 0.32, binder content of 450 kg/m3, and replacement of Portland cement (PC) with 20 and 40% slag and natural pozzolan. 2 geopolymer mortar mixtures with KOH and NaOH as activator were designed. To evaluate their mechanical properties, Compressive strength and tensile adhesion strength were carried out. Also, in order to investigate their durability features against sulfuric acid attack, mortar specimens length Change, compressive strength loss, and weight loss were investigated. According to the results, the use of cement substitute materials (furnace slag and natural pozzolan) reduced the compressive strength by 25%, increased the adhesion strength by 50%, and reduced the length change, weight loss and compressive strength loss of the samples exposed to sulfuric acid. Also, the use of geopolymer mortars had the better performance than the control sample, so that more than 40% increase in compressive strength, about 150% increase in adhesion resistance and approximately 50% decrease in length change and weight loss and compressive strength loss compared to control sample in the sulfuric acid environment. In general, the test results show the proper performance of geopolymer repair mortars in aggressive acidic environments compared to cement-based mortars.

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1- Introduction

In recent decades, the repair of concrete structures damaged by environmental factors and loads has been a significant issue in various parts of the world. Acid attack, especially sulfuric acid attack, is one of the major causes of failure in concrete structures. After diagnosing the cause of the failure, choosing the appropriate repair materials is the most important challenge.

According to previous research, the use of furnace slag and natural pozzolan increase the resistance of concrete to sulfuric acid attack [1-3]. In addition, geopolymer materials performed well against acid attack, due to their lower levels of calcium hydroxide [4, 5]. This study aims to compare cement-based repair mortars containing furnace slag and natural pozzolan, and geopolymer mortars against sulfuric acid attack, which have not yet been studied in the form of repair mortars.

Compressive strength test (CS) and adhesion resistance test (AR) were used to evaluate the mechanical properties of hardened mortars. Also, in order to investigate their durability features against sulfuric acid attack (pH=1), mortar samples length Change (LC), compressive strength loss (CSL), and weight loss (WL) were investigated.

2- Experimental program

In this study, Portland cement Type 2, normal sand, furnace slag, and natural pozzolan as supplementary cementitious material (SCM) were used for making cement-based mortar samples. Besides, furnace slag and silica fume (SF) as pozzolan and sodium hydroxide, potassium hydroxide and sodium silicate (SS) as alkaline activator solution (AS) were utilized for producing geopolymer based mortars.

According to previous studies, five cement-based mixtures containing SCM with water to cement ratio of 0.32 and 2 geopolymer-based mixtures containing silica fume with alkaline activator concentration of 6 molars were selected as the final mix designs. The mix proportion of cement-based mortar and geopolymer-based mortars are indicated in Table 1 and Table 2, respectively.

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Table 1. mixture proportion of cement-based mortars.

Materials and proportions	OPC (control)	S20	S40	N20	N40
Ordinary Portland cement (kg/m^3)	450	360	270	360	270
Furnace slag (kg/m^3)	0	90	180	0	0
Natural pozzolan	0	0	0	90	180
Free water (kg/m^3)	144	144	144	144	144
Fine aggregate (kg/m^3)	1805	1797	1789	1785	1764
Superplasticizer (% of cementitious materials)	1	1	1.2	1.2	1.5
Flow table (mm)	150	160	160	170	170

Table 2. mixture proportion of geopolymer based mortars.

Mixture ID	AS	Molarity	Agg to Pozz	AS to Pozz	SF (%)	SS to AS
KOH	KOH	6	2.75	0.6	5	0.4
NaOH	NaOH	6	2.75	0.6	5	0.4

Table 3. summary of test results

Tests	Time (Days)		OPC (control)	S20	S40	N20	N40	KOH	NaOH
CS (MPa)	28	Lime water curing	47.8	51.7	47.8	44	35.5	75	75.2
	90		60	64	58	52	44	82	85
AR (MPa)	28		1.5	2.3	1.7	1.9	1.5	3.1	3.6
LC (Ɛ)	90	Acid sulfuric solution	0.71	0.6	0.48	0.55	0.48	0.46	0.41
CSL (%)	56		59	58	50	58	54	28	30
	90		71	64	54	68	62	32	35
WL (%)	56		31	26	21	28	23	6	2
	90		40	33	24	36	30	17	12

3- Test results

The summary of mechanical and durability test results is indicated in Table 3. As can be seen from the results, geopolymer mortars, especially the mixture containing potassium hydroxide, had the highest compressive strength. Among the cement-based samples, due to the delay at the beginning of the pozzolanic activity of SCM, the compressive strength of the OPC sample was highest in the early ages. Over time, specimens containing furnace slag had more compressive strength than the OPC. Due to the more sticky nature of their paste, geopolymer mortars have a higher adhesion resistance than cement-based samples. Besides, the use of SCM increased the adhesion resistance of cement-based mortars.

Based on the results of mortar length change exposed to acid sulfuric, with the increase in the percentage of replacement of slag and natural pozzolan instead of cement, the growth in sample length has decreased, and in general, the performance of slag and natural pozzolan is similar to each other. At the same time, the length change of geopolymer-based mortars was less than the cement-based mortars. Also, the results of both compressive strength loss and weight loss tests confirm the proper performance of geopolymer mortars. However, among the cement base mixtures, the sample containing 40% furnace slag had the best performance against sulfuric acid.

4- Conclusions

The summarized experiment results of this research are mentioned as the following:

- Geopolymer mortars indicate more compressive strength and adhesion resistance than the cement-based samples. They have also performed better against sulfuric acid attacks.
- Although the use of furnace slag in cement-based mortars reduces the compressive strength of the specimens, especially in the early ages, these mortars have more adhesion resistance than the control mixture, and they are highly resistant to the sulfuric acid attack.
- Samples containing natural pozzolan have the lowest compressive strength and adhesion resistance among cement-based mortars, but the use of it, due to the reduction of the calcium hydroxide in the mortar structure, increases the durability of the mortar against sulfuric acid.
- According to the results of all experiments in this study, geopolymer-based mortars perform better than cement-based mortars against sulfuric acid. Among the cement-based mixtures, mortar containing 20 percent furnace slag has the best performance.

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