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Effect of Four Iranian Natural Pozzolans on Concrete Durability Against Sulfate Attack

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ABSTRACT

Sulfate attack is one of the most important problems concerning the durability of concrete structures. Natural pozzolans are the natural mineral admixtures which can improve concrete durability against sulfate attack. In this paper, the sulfate resistance of concrete and mortar samples made from ordinary Portland cement containing three different portions of four types of natural pozzolans (Eskandan Pumice, Khash Pumice, Abyek Tuff and Jajrood Trass) was studied. Strength reductions and mass changes of the concrete samples, immersed in sodium sulfate solution, as well as the expansion of mortar prisms, immersed in sodium and magnesium sulfate solutions, were monitored. It was observed that the resistance of mixtures containing natural pozzolans was higher against both sodium sulfate and magnesium sulfate attacks compared to the reference cement.

KEYWORDS

Sulfate Attack, Natural Pozzolan, Compressive Strength, Mortar Expansion.

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1- INTRODUCTION

Sulfate attack is a critical issue for a variety of concrete structures around the world. This process of deterioration reduces the service life of structures, which may cause serious economic problems as well as life losses. Normally, sulfate attack occurs when concrete is in contact with sulfate ions that may be available in soil, underground water, or sea water. Generally, in a usual sulfate attack, sulfate ions react with calcium hydroxide in hydrated cement paste and form ettringite and gypsum. Both ettringite and gypsum are expansive materials and occupy larger volumes than the reactant materials in the hydrated cement paste. Accordingly, pressure occurs inside the hydrated cement paste pores, which can cause cracking. The mentioned crack formation can eventually result in a total failure of concrete structure [1].

Commonly, in order to mitigate the problems due to sulfate attack, Portland cements Type II or V are used instead of the ordinary type of Portland cement (Type I) [2]. There is another approach for reducing the problems with sulfate attack that is more recent than using Portland cements Type II and V. In this approach, Portland cement is partially replaced with supplementary cementing materials such as slag, silica fume, natural pozzolans, etc. It is well understood that supplementary cementing materials can improve the resistance of Portland cement against sulfate attack [3].

There is a variety of different types of natural pozzolans resources in Iran. Therefore, it is necessary to study the performance of those pozzolans when used in mortar and concrete in order to develop the options for improving the performance of concrete structures in the country. Considering this fact, in the present paper, the effect of four Iranian natural pozzolans on improving the resistance of mortar and concrete against sulfate attack is studied.

2- METHODOLOGY, DISCUSSION, AND RESULTS

The aggregates used in this experimental study were prepared in accordance with the Iranian standard. The cement used was Portland cement Type I-425. The samples of natural pozzolans were obtained from the resources in Eskandan, Jajrood, Abyek, and Khash. Considering different replacement percentages, 12 blends of Portland cement with naturals pozzolans were prepared. In addition, a control sample was considered in order to compare the performance of the samples of natural pozzolans. The blends are presented in Table 1. In order to have consistent results, the water to cement ratio in all samples was 0.5, and the concrete slump was kept between 6 and 8 cm using superplasticizer.

The compressive strength test was performed on 10-cm cubic concrete samples as per the Iranian standard (ISIRI 3206). The test was performed at ages of 7, 28, 91, and 180 days after casting. On similar cubic concrete samples, the sulfate attack was also studied. The concrete samples were first prepared and cured in saturated limewater for 28 days. Then, they were immersed in 5% sodium sulfate solution for 180 days, and the mass change and the compressive strength were studied.

Additionally, prismatic mortar samples were prepared for ASTM C1012 expansion test, and the expansion of mortar samples immersed in both sodium and magnesium sulfate solution was studied periodically up to 180 days.

The compressive strength performed on the concrete samples cured in limewater showed that the samples containing pozzolans had maintained an acceptable compressive strength after 6 months. Among the studied pozzolans, Jajrood Trass showed more activity by maintaining higher compressive strength at the lower ages. Among all samples, those contained 20% and 25% Abyek Tuff performed the worst with regards to achieving the expected compressive strength.

When the compressive strength of the concrete samples immersed in sodium sulfate solution was compared to the compressive strength of the ones cured in limewater, it was found that the control sample had the highest compressive strength decrease. Additionally, the changes in the mass of concrete samples showed that pozzolanic samples had lower mass increases. As the mass increase is due to the formation of ettringite and gypsum, the lower mass increase is associated with the resistance against sulfate attack. Thus, it was confirmed that the four studied pozzolans improved the resistance against sulfate attack considering the compressive strength development and mass changes.

With regards to the ASTM C1012 expansions of mortar prisms prepared with blends presented in Table 1, in general, the samples contained pozzolans had lower expansions than the control sample. This fact denotes that the pozzolanic blends were more resistant against sodium and magnesium sulfate attacks. Most of the blends could be considered as high sulfate resistant blended Portland cement considering the limitations assigned by ASTM C1157.

3- CONCLUSIONS

1- Overall, the studied pozzolans did not cause considerable compressive strength reductions when added to Portland cement, especially when older ages were considered. Accordingly, from the viewpoint of compressive strength, they were satisfactory.

2- When immersed in sodium sulfate solution, concrete samples maintained their compressive strength better than the control sample. Likewise, they had lower mass increase than the control sample. Additionally, when the expansions of mortar samples were studied in sodium and magnesium sulfate attacks, in general, the pozzolanic samples showed reduced expansions compared to the control samples. Therefore, the resistance of concrete containing the four studied Iranian natural pozzolans was improved.

TABLE 1. THE CONCRETE MIXTURES ROPORTIONS

	Pozzolan type	Water to cement ratio	Replacement (%)	Cement (Kg/m^3)	Pozzolan (Kg/m^3)	Water (Kg/m^3)	Aggregates (Kg/m^3)
Control	-	0.5	0	350	0	175	1750
P10	Eskandan Pumice	0.5	10	315	35	175	1750
P15	Eskandan Pumice	0.5	15	297.5	52.5	175	1750
P20	Eskandan Pumice	0.5	20	280	70	175	1750
A15	Abyek Tuff	0.5	15	297.5	52.5	175	1750
A20	Abyek Tuff	0.5	20	280	70	175	1750
A25	Abyek Tuff	0.5	25	262.5	87.5	175	1750
K15	Khash Pumice	0.5	15	297.5	52.5	175	1750
K20	Khash Pumice	0.5	20	280	70	175	1750
K25	Khash Pumice	0.5	25	262.5	87.5	175	1750
T15	Jajrood Trass	0.5	15	297.5	52.5	175	1750
T20	Jajrood Trass	0.5	20	280	70	175	1750
T25	Jajrood Trass	0.5	25	262.5	87.5	175	1750

4- REFERENCES

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