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The Effect of Pumice and Silica Fume on the Mechanical Properties and Durability of Concrete

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ABSTRACT: Portland cement production has caused problems such as air pollution, energy consumption, loss of natural resources, exacerbation of greenhouse effects, and global warming which have some economic issues. The use of pozzolans in the production of concrete decreases the negative points of the above-mentioned problems and improves the mechanical properties and durability of the concrete in long run. In this paper, the effects of Taftan natural pumice powder and silica fume on the mechanical and durability properties of concrete are investigated. For this purpose, 18 concrete mixes were considered for two water to cementitious materials ratios of 0.4 and 0.45. Taftan natural pumice was replaced for Portland cement at 0, 10 and 20 percent and silica fume at 0, 7, and 10 percent. The results showed that using Taftan natural pumice improves the mechanical and durability properties of concrete. After 90 days, the highest values of compressive strength, tensile strength, and sulfate resistance of mixes containing 10% Taftan natural pumice, 10% silica fume, and mixes containing 20% Taftan natural pumice, 10% silica fume were achieved. For these mixes, the capillary absorption and electrical resistance results were better compared to the other mixes, too. On the other hand, the use of the Taftan natural pumice instead of a percentage of Portland cement has reduced the cost of production concrete.

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1- Introduction

Due to the high volume of concrete that is done annually in our country, not paying attention to the environmental problems caused by the production of Portland cement can have devastating consequences. Therefore, efforts to find suitable alternatives to Portland cement continue, and civil engineers are always looking for the best pozzolans and the optimal replacement percentage of each of them for various uses to save both costs and concrete with mechanical properties. And have higher durability than the concrete used for construction in the country today. Pumice and silica fume are among the pozzolans used in the manufacture of concrete.

Pumice is a volcanic rock and is found in white, gray, pink, pale yellow, or brown, with grains larger than 2 mm, called pumice, and smaller grains called pumicit [1]. Due to a large amount of gas and water vapor in the composition of pumice and pumicit, the specific gravity of these materials is usually very low and their volume is high (the specific gravity of pumice is often less than one). Pumice powder is obtained by grinding pumice aggregates, which do not require much energy due to the structure of pumice aggregates. Turkey is known as the largest source of pumice in the world [2]. In Iran, there are significant sources of these natural pozzolans in the range of old volcanoes such as Taftan in Sistan and Baluchestan (pumice used in this study), Damavand near Tehran and Sahand and Sabalan in East Azerbaijan.

The number of researches that have been done so far on the effect of pumice powder on the properties of concrete is small and most of the researches that use pozzolanic pumice in concrete construction use pumice as aggregate (as a substitute for sand) and for making light concrete. Construction or other non-construction structures have been used and on the other hand, experiments to evaluate the mechanical properties and durability of concrete have not yet been performed on designs containing both pozzolans of natural Taftan pumice and silica fume. Also, at a lower cost, the effect of Taftan natural pumice powder and silica fume on compressive strength, tensile strength, and durability of concrete is studied.

2- Methodology

The aggregates used in this experimental study were prepared under the ASTM C33 standard.

In this study, Taftan natural pumice was used in the manufacture of concrete samples and pozzolan silica fume was used to compare and improve the chemical and mechanical behavior of Taftan natural pumice. To investigate the pozzolanic role of Taftan natural pumice and silica fume in concrete, 18 mixed designs in 2 water to cementitious materials ratios of 0.4 and 0.45 were considered that for each water to cementitious materials ratios one design was considered as a control design and on concrete at the ages of 28 and 90 days mechanical and durability tests including

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Table 1. Specifications of mix design made with water to cementitious materials ratio of 0.4

mix design	pumice (%)	silica fume (%)	gravel (kg/m^3)	sand (kg/m^3)	water (kg/m^3)	cement (kg/m^3)	pumice (kg/m3)	silica fume (kg/m^3)	super lubricant
P0SF0	0	0	901.6	901.6	156.8	392	0	0	0.7
P10SF0	10	0	892.4	892.4	155.2	349.2	38.8	0	0.9
P20SF0	20	0	889.6	889.6	154.7	309.4	77.4	0	1.05
P0SF7	0	7	884.1	884.1	153.7	357.5	0	26.9	0.9
P0SF10	0	10	882.3	882.3	153.4	345.2	0	38.4	0.95
P10SF7	10	7	876.8	876.8	152.5	316.4	38.1	26.7	1.05
P10SF10	10	10	866.6	866.6	150.7	301.4	37.7	37.7	1.1
P20SF7	20	7	869.4	869.4	151.2	275.9	75.6	26.5	1.2
P20SF10	20	10	856.5	856.5	149	260.7	74.5	37.2	1.25

Table 2. Specifications of mix design made with water to cementitious materials ratio of 0.45

mix design	pumice (%)	silica fume (%)	gravel (kg/m^3)	sand (kg/m^3)	water (kg/m^3)	cement (kg/m^3)	pumice (kg/m3)	silica fume (kg/m^3)	super lubricant
P0SF0	0	0	885.4	885.4	175.1	389.2	0	0	0.6
P10SF0	10	0	878.1	878.1	173.7	347.4	38.6	0	0.75
P20SF0	20	0	864.5	864.5	171	304	76	0	0.95
P0SF7	0	7	876.3	876.3	173.3	358.2	0	27	0.75
P0SF10	0	10	866.3	866.3	171.4	342.7	0	38.08	0.8
P10SF7	10	7	853.6	853.6	168.8	311.4	37.5	26.3	0.9
P10SF10	10	10	848.1	848.1	167.8	298.2	37.3	37.3	1
P20SF7	20	7	844.5	844.5	167	271	74.2	26	1.1
P20SF10	20	10	835.4	835.4	165.2	257	73.4	36.7	1.15

compressive strength, tensile strength, sulfate resistance, capillary absorption, and electrical resistance were performed. In this study, Taftan natural pumice was replaced for cement at 0, 10, and 20 percent and silica fume at 0, 7, and 10 percent. The mixed designs are presented in Tables 1 and 2.

In this study, the compressive strength test was performed on 10 cm cubic concrete samples as per the ASTM C39 standard. The test was performed at the ages of 28 and 90 days. To perform a tensile strength test, standard cylindrical concrete specimens with a diameter of 15 cm and a height of 30 cm after curing were tested at ages of 28 and 90 days (ASTM C496).

To evaluate the resistance to sulfate attack, the samples were first placed in a pool of water for wet processing for 7 days and then transferred to sodium sulfate solution at a concentration of 5% and after reaching the experimental ages (28 and 90 days) were removed from the solution and their performance was evaluated by examining their appearance (photographing samples), calculating weight change and measuring compressive strength. It should be noted that in this study, the sulfate attack resistance test was performed on samples that had the highest compressive strength among their designs (optimal samples).

Capillary adsorption (ASTM C1585) and electrical resistance tests were also performed on 10 cm cubic concrete samples to further evaluate the durability of the mix design.

3- Results and Discussion

The results of this study showed that the replacement of Taftan natural pumice for Portland cement in concrete in many cases improves its mechanical properties and durability compared to the control design and also has proximity to the designs containing silica fume. In the compressive strength test, the design containing 10% Taftan natural pumice and 10% silica fume (with 24% increase in 90-day concrete resistance), in the tensile strength test, the design containing 10% Taftan natural pumice and 10% silica fume (with 30% increase in 90-day concrete resistance), in the sulfate resistance test, the design containing 10% Taftan natural pumice and 10% silica fume (with 32% increase in 90-day concrete compressive strength), in the capillary absorption test, the design containing 20% Taftan natural pumice and 10% silica fume and in the electrical resistivity test, the designs containing 20% Taftan natural pumice and 10% silica fume (all with water to cementitious materials ratio of 0.4) were optimized. N. Kabay [3] and Ramezanianpoor [4] have reported similar results.

4- Conclusion

1) 28-day compressive strength of designs in which pumice alone was used has decreased the compressive strength of the control design, but with the passage of time and reaching the age of 90 days, the compressive strength

of the design containing 10% pumice has increased than the control design (with about a 5% increase in the compressive strength of concrete) because pumice pozzolans need time to perform their pozzolanic activities.

2) The mechanical properties of the designs in which natural Taftan pumice and silica fume are used simultaneously are very suitable and after 90 days the highest values of compressive strength and tensile strength are assigned to the design containing 10% pumice and 10% silica fume (with more than 20% increase in compressive strength of concrete).

3) In the sulfate attack, capillary absorption and electrical resistance tests were performed to evaluate the durability of concrete. The designs with the highest percentage of pozzolan replacement showed the best performance among the samples. The design containing 10% pumice and 10% silica fume and in capillary adsorption and electrical resistance tests, the design containing 20% pumice and 10% silica fume were optimized because in these designs the porosity of concrete was reduced to a minimum.

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