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Evaluation of various content of zeolite on the mechanical and durability properties of concrete at high temperatures

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ABSTRACT: One of the major environmental contamination factors is cement production and of major damaging factors of reinforced concrete structures is high temperatures. In this study, the effect of substitution of 10 and 20% of cement weight with zeolite on mechanical and durability properties of concrete structures at high temperatures has been investigated. Mechanical properties including compressive and tensile strength of concrete in the hot condition and the durability characteristics of the concrete after cooling, including surface water absorption, the penetration depth of water, electrical resistance and weight loss have been investigated. This study covers temperatures of 28 to 800 °C. The results showed that the replacement of cement with zeolite reduced the compressive strength and tensile strength of 28 and 42 days. This assessment at high temperatures showed that although the replacement a portion of cement with zeolite decreased the compressive strength of normal concrete, the normalized compressive strength improved at most tested temperatures. In addition, it was observed that by substitution 10 and 20% of cement weight with zeolite, the tensile strength of normal concrete at high temperatures increased by 21 and 13 percent averagely. This improvement for normalized tensile strength was 22 and 14%, respectively for mentioned substitution. Although the increase in the test temperature has had adverse effects on the durability of concrete, the replacement of cement with zeolite has improved the durability specification. The best durability properties of concrete were achieved in samples containing higher content of zeolite.

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1. INTRODUCTION

The progress of the industry, which is growing by humans every day, is a major contributing factor in environmental pollution. The contribution of concrete to the production of these contaminants is 6% [1]. Reducing cement consumption in concrete, by replacing a portion of cement with materials that do not contribute to contamination of the environment, reduce air pollution [2]. The pozzolans are among these materials, their commercial use in the construction industry may be practical if their resources are available. Zeolite is a natural pozzolan is available in Iran-Semnan.

In addition to the earthquake and the wind that the structures must resist against them, a fire may impose irreparable injuries and financial losses. Therefore, an understanding of the real behavior of concrete at high temperatures is of great importance. Reinforced concrete structures, besides having resistance during the fire, should have acceptable durability characteristics for continuing to operate after the fire. There are several types of pozzolans around the world that have been studied by previous researchers. Among these studies, the impact of these pozzolans on the mechanical and durability properties of concrete at ambient temperature has been clarified. The experimental study on the compressive and tensile strength of samples containing zeolite at ambient temperature showed that the compressive strength of samples with zeolite was approximately the same or slightly lower than normal concrete. The replacement of 10% cement weight by zeolite increased the 28 days and 90 days' tensile strength. However, substitution 15% of cement weight by zeolite decreased tensile strength [3]. Investigation of mechanical and durability properties of samples with silica-fume, fly ash and slag at temperatures of 200, 400, 600 and 800 degrees showed that at temperatures lower than 600 degrees, the samples containing fly ash and slag had the best performance [4].

One of the methods for determining the durability characteristics of concrete is the sorptivity test. This method is based on the tendency of concrete to absorb and transfer water from the pores. As much as this coefficient is less, the durability of concrete is higher. This method can be used to classify concrete quality[5]. Another criterion for determining the durability of concrete structures is electrical resistance. This test, which determines the potential for corrosion of reinforcement in concrete, is also used in [6], [7] to evaluate the durability of concrete.

An extensive review of previous studies has shown that mechanical and durability properties of concrete containing

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Table 1. The compressive and Tensile strength of Specimens at ambient temperature

ID	N	Ze10	Ze20
C-28	47.17	34.16	37.27
C-42	53.38	49.43	48.93
T-28	2.57	2.46	2.45
T-42	3.03	2.56	2.53

zeolite at high temperatures have not been investigated. Also, most of the studies that examined the mechanical properties of normal concrete at different temperatures conducted tests on cooled specimens. However, a good understanding of the behavior of concrete during a fire achieve when tests are done in a hot condition. Therefore, in this study, the compressive and tensile strength of normal concrete has been tested at 28-800 centigrade, and the effect of the replacement of 10 and 20 of cement weight with zeolite has been clarified. Also, the durability characteristics were tested using sorptivity tests, water penetration depth tests, electrical resistance tests, and weight loss tests.

2. METHODOLOGY

In this study three groups of concrete mixes were studied: concrete mixes without pozzolan (N), concrete mixes containing 10% of Zeolite (Ze10) and concrete mixes containing 20% of Zeolite (Ze20). The coarse aggregate was calcareous with a maximum size of 19 mm, the fine aggregate was river sand and ordinary Portland cement type 2 was used in the mix designs. From any mixture, 3 cubic specimens and 3 cylindrical specimens were cast for compressive and tensile strength, respectively. Also from each concrete mixture, 6 cubic specimens were cast for the durability tests and in total 426 specimens were prepared and tested for this study. The mechanical specification tests were carried by a 3000 KN testing machine and the heat source was an electric furnace with a heat capacity of 1200 °C. The concrete samples were kept in the furnace averagely for 180 minutes to make sure that the samples are under a steady-state thermal condition. After removing specimens from the oven, the mechanical specification of specimens was tested immediately.

3. RESULTS AND DISCUSSION

The compressive strength and tensile strength of the specimens were measured according to BSEN 12390-3 and ASTM C496/C 496M–04, respectively after 28 and 42 days of curing [8] [9]**.** Table 1 gives the results of the test at ambient temperature. The substitution of 10 and 20% of cement weight with zeolite reduced the 28-day compressive strength of normal concrete by 41.7 and 8.33%, respectively. These reductions for the 42-day compressive strength was 27.58 and 21%, respectively. In addition, the 42-day compressive strength of N, Ze10 and Ze20 were 13.17, 44.96 and 31.31 higher than 28-day compressive strength, respectively. In terms of tensile strength, the application 10 and 20% of zeolite decreased 28-day tensile strength by 4.31 and 4.60% respectively. The mentioned reduction for the 42-day tensile strength was 15.56% and 16.48%, respectively. In addition, the 42-day tensile strength of N, Ze10 and Ze20 were 17.79, 3.94 and 3.23% higher than that of 28-day tensile strength, respectively.

4. CONCLUSIONS

Variations of N, Ze10 and Ze20 were similar at different temperatures, and the replacement of 10 and 20% of cement weight by zeolite at the studied temperatures reduced the compressive strength of normal concrete averagely by 7.89% and 67.7%, respectively. It was also observed that at temperatures below 450 °C, the Ze10 had higher compressive strength than Ze20. However, above 450 ° C this trend reversed. The investigation of normalized compressive strength showed that zeolite improved or has decreased marginally this parameter. Comparison of the normalized compressive strength of the Ze10 and Ze20 samples at the studied temperatures was similar to compressive strength results.

The study of concrete tensile strength showed that zeolite had a significant effect on the improvement of tensile strength and the normalized tensile strength of concrete at high temperatures. The replacement of 10 and 20% of cement weight with zeolite improved the tensile strength by 21.88% and 13.51%, respectively. The improvement of the normalized tensile strength for Ze10 and Ze20 was 49% and 39%, respectively.

In the study of concrete durability, it was observed that an increase in the test temperature brought undesirable effects on this characteristic. With increasing test temperature from 100 to 800 centigrade, the sorptivity coefficient of N, Ze10 and Ze20 samples increased by 42, 37 and 182 percent, respectively. In this temperature range, the penetration depth of the samples increased by 53, 58 and 103 percent, and the electrical resistance of N, Ze10 and Ze20 samples decreased by 74, 73 and 76 percent, respectively.

In the sorptivity test, the replacement of 10 and 20% of cement weight with zeolite improved this parameter at the studied temperatures averagely 8 and 40%, respectively. This assessment in the penetration depth of water test and electrical resistance tests showed an improvement of 9 and 33% in specimens containing 10 and 20 % of zeolite, respectively. Furthermore, by increasing the temperature test from 100 to 800 centigrade, the weight loss of N, Ze10, and Ze20 increased by 328, 385, and 355%, respectively.

Therefore, according to the results of this study, it can be concluded that the application of zeolite in concrete can maintain the mechanical and durability properties of normal concrete at high temperatures. Meanwhile, it was observed that in mechanical and durability tests substitution 10 and 20 % of cement weight with zeolite resulted in the best performance at high temperatures, respectively. Because the specimens containing 20% zeolites had an acceptable performance in both aspects of mechanical and durability properties, it is recommended to substitute 20% of cement weight with zeolite in mixing plan of concrete structure with the risk of fire accidents to meet both engineering consideration and environmental issues.

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