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Mechanical Properties of Concrete Incorporating Bentonite and Zeolite as Replacement of Cement

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ABSTRACT: The production of concrete consumes huge amounts of natural resources. Due to the consumption of natural resources for cement production, using industrial waste materials has gained interest among researchers. Environmental issues are one of the most important issues that should be taken into consideration. Zeolite and bentonite are considered as natural pozzolans, they are easy to extract and count as environmentally-friendly raw material compared to ordinary Portland cement (OPC). In the current study, these materials were utilized blended with other materials and individually. Compressive strength, water absorption, tensile strength, and elastic modulus of concrete samples were evaluated. Moreover, 10 different mixing designs were designed to produce samples in the same curing condition with different content of bentonite and zeolite. These samples were cured for 7, 28, and 90 days. To investigate the properties of these materials as an alternative to OPC in the concrete, the results are compared with the blank sample. The optimum mixture was obtained by 6 wt. % of zeolite and 6 wt. % of bentonite, which was gained 93% of the compressive strength of the blank sample, i.e., 12.25 MPa, after 28 days of curing. This study also showed that the water absorption of samples with zeolite and bentonite had increased in comparison with the blank sample and the optimum amount in tension was observed 10 wt. % of bentonite.

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1. INTRODUCTION

Increasing population growth and the need for housing in recent decades have led to the need to meet the needs of the construction industry, using materials that are both economically viable and impose the least damages to the environment. Environmental protection is debated in many developing countries, annually, 7% of CO_2 production occurs by the cement industry, causing serious damages to the environment. Researchers are looking for inexpensive and cost-effective pozzolans benefitting from both good adhesion and improve the mechanical properties and durability of concrete [1]. The use of pozzolans in concrete mixing design has an important role that the source of these pozzolans and additives could be natural materials or industrial wastes for which, much energy is not consumed during the process of production [2]. One of the issues studied in the use of bentonites is a measurement of compressive strength and durability of concretes containing bentonite, the results of which have shown that bentonite at an early age (7 and 14 days) did not acquire good strength and caused weakness in the results of compressive strength test, but exhibited a great strength at older ages [3]. In addition, in another study, the concretes containing natural zeolite with a water to cement (w/c) ratio of 0.4, showed a higher compressive strength at the ages of 3, 7, 28, and 90 days [4, 5]. In the present study, the effect of zeolite and bentonite application is simultaneously considered as cement substitutes. The main purpose of replacing pozzolans with cement, which have good conditions in terms of improving the compensation of cement hydration process due to the replacement of bentonite and zeolite, and can be used in the production of new chains of environmentally friendly cement.

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2. EXPERIMENTAL PROGRAM

In this study, cement-substituted pozzolans include zeolite with the replacement ratio of 6, 10, and 16%, and bentonite with a replacement ratio of 6, 10, and 16% of the weight of cement. The compressive strength tests at the ages of 7, 28, and 90 days were performed on cylindrical specimens according to ASTMC39. All specimens were built under the same conditions, then poured into 20×10×10 cylindrical specimens, and after 24 hours, the specimens were demolded (Fig. 1) and kept in water at room temperature.

In this study, for building the ordinary concretes, Portland cement type II of Shahrood Cement Company was used, also for making pozzolanic concrete from zeolite and bentonite prepared from mines of Semnan province, milled by Negin Powder Company of Semnan, used as pozzolans together with the cement. The zeolite and bentonite used in this test were used in powder form with the same grading. The aggregates used in this test were washed sand passed through a sieve #4

Fig. 1. The cylindrical specimens

Table 1. Mix designs plan in this study

Name	Cement (Kg)	Bentonite (Kg)	Zeolite (Kg)
C-250	250	0	0
B6-C-Z6	220	15	15
B6-C-Z10	210	15	25
B6-C-Z16	195	15	40
B10-C-Z6	210	25	15
B10-C-Z10	200	25	25
B10-C-Z16	185	25	40
B16-C-Z6	195	40	15
B16-C-Z10	185	40	25
B16-C-Z16	170	40	40

(4.75 mm) and coarse-grained aggregates with the same grain size (maximum nominal size of 8 mm).

The mixing of materials in the laboratory has been as follows:

First, sand was poured into the mixer, and ¼ of the mixing water was added to it so that the sand was well mixed and its surface became wet. Then, ¼ of the cement was poured into the mixer and some mixing water was added. Until the cement was well mixed with the sand and a layer of cement completely covered the aggregates and became ready for hydration, then zeolite and bentonite combined in two stages were added and finally, the remaining water was added to the mixer. In the mixing design Table, the naming is as follows: the reference specimen with a cement grade of 250 kg/m^3 is denoted with C-250, and in the specimens shown as B6-C-Z10, the number in front of B represents the percentage of bentonite and the number after Z indicates the percentage of zeolite and the letter C indicates the presence of cement in the mix design (see Table 1).

3. RESULTS AND DISCUSSION

In the early ages, the specimens containing bentonite and zeolite were accompanied by a decrease in strength, to the extent that a decrease in compressive strength was observed in all specimens compared to the reference specimen. In general, as per the addition of pozzolans, the compressive strength decreases, which usually decreases to some extent with increasing age of curing and performing all pozzolanic reactions compared to the reference specimen.

The tensile strength test was carried out according to ASTMC496-71. According to the obtained results, the specimens containing 10% bentonite had the highest tensile strength. Evaluation of 7 and 28-day tensile strength from the diagram of Fig. 3, showed that the mixing design of the reference specimen and B6-C-Z6 had not changed significantly compared to the other mixing designs. The growing trend of strength at older ages is due to the higher percentage of bentonite in the specimens, where B10-C-Z16 and B16-C-Z16 have the highest growth of tensile strength from 7 to 28 days. On average, in the replacement ratio of 20 to 32% bentonite and zeolite, the tensile strength has increased by about 35% from 7 to 28 days.

4. CONCLUSION

In this paper, the performance of concrete produced with zeolite and bentonite in compressive, tensile strength, etc. was investigated. Considering the effect of using zeolite and bentonite on compressive and tensile strengths, the following results have been obtained:

-In the early ages, the compressive strength of the specimens had decreased, but in the older ages, the compressive strength increased due to the improvement of the hydration rate and the increase in silicate gel that occurs during the pozzolanic reactions. Replacement of 12 to 16% bentonite and zeolite increased the compressive strength.

-The addition of bentonite and zeolite had increased the split tensile strength. The specimens containing 10% bentonite had the highest tensile strength. In the replacement ratio of 20 to 32% bentonite and zeolite, the tensile strength had increased by about 35% from 7 to 28 days, and the best mixing design in tensile after 28 days was B10-C-Z16 with a strength equal to 2/85.

As the bentonite clay is very hydrophilic and the pores in zeolite have higher water absorption than pure cement, increasing bentonite and zeolite raised the water absorption percentage of the produced concrete.

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