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Research paper

Review and determining the influence of zeolite on concrete strength under high temperature conditions

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Abstract

in this paper, to verify the effect of zeolite on the strength of concrete and the effect of high temperatures on this type of concrete 5 composition, containing different percentages zeolite (5%, 10%, 15% and 20%) with fixed water to cement ratio for perception of optimized percent of zeolite is made and influence of heat on compressive strength and ultrasonic speed waves was checked . according to tests, it is concluded that the replacement of 10% cement with zeolite at ratio water to cement 0.45 at ages 7, 28 and 90 days, is the optimized replacement level to zeolite.

Keywords: *Concrete; Zeolite; Compressive Strength; High Temperature.*

1. Introduction

concrete which is used for construction consist of mainly aggregates of limited maximum size that meet certain characteristics related to their mechanical, chemical, and properties and which are merged by a cement and water. [1].
The durability of concrete can be defined as its ability to resist actions from the service environment, physical, chemical, and biological attacks, and any process that tends to deteriorate it. Therefore, a healthy and compact concrete refers to a concrete that maintains its original form and its resistance under service in time [1]. Using Zeolite can help to improve this condition as well.
in this paper, to verify the effect of zeolite on the strength of concrete and the effect of high temperatures on this type of concrete 5 composition, containing different percentages zeolite (5%, 10%, 15% and 20%) with fixed water to cement ratio for perception of optimized percent of zeolite is made and influence of heat on compressive strength and ultrasonic speed waves was checked.

2. Literature review

Nagrockiene [2] showed that the predicted freeze-thaw resistance calculations revealed 3.3 times higher resistance of concrete modified with up to 10% of natural zeolite.
Uzal [3], investigated properties and hydration characteristics as well as paste microstructure of blended cements containing 55% by weight zeolitic tuff composed mainly of clinoptilolite mineral.
Perraki [4], concluded, the examined zeolite consists mainly of heulandite type-II and is a pozzolanic material that contributes to the strength development of zeolite-cement mixtures, the consumption of Ca(OH)2 formed during the hydration of Portland cement and the formation of cement-like hydrated products. Finally, the addition of zeolite up to 20% w/w does not significantly affect the physical and mechanical properties of the blended cements.
Ramezanianpour [5] assessed the effects of natural zeolite, as a supplementary cementitious material, on micro and macro properties of pastes and concretes having different water-to-cementitious materials ratios. The microstructure analysis showed modifications in transition zone and quality of pastes by use of natural zeolite.
Vejmelková [6] presented a complex analysis of engineering properties of concrete containing natural zeolite as supplementary cementitious material in the blended Portland-cement based binder in an amount of up to 60% by mass. The studied parameters included basic physical characteristics, mechanical and fracture–mechanics properties, durability characteristics, and hygric and thermal properties. Experimental results showed that 20% zeolite content in the blended binder is the most suitable option.
Eskandari [7], As a result of performed tests, showed that increase of mechanical characteristics is not considerable but make significant decrease in penetration of chloride ion and increase electrical resistivity that are appropriate option for controlling of corrosion in reinforced concrete structures.
Ahmadi [8], evaluated the effectiveness of a locally quarried zeolite in enhancing mechanical and durability properties of concrete and also compared with other pozzolanic admixtures. The results indicated that natural zeolite was not as reactive as silica fume but it showed a good pozzolanic reactivity.

3. Consumable materials

3.1. Course aggregate

Grading test in accordance with standard ASTM c 136-84a is performed. Curve of grain aggregate used in concrete is the same as below form.

3.2. Sand aggregate

Consuming sand is consistent with the range of standard ASTM 33.

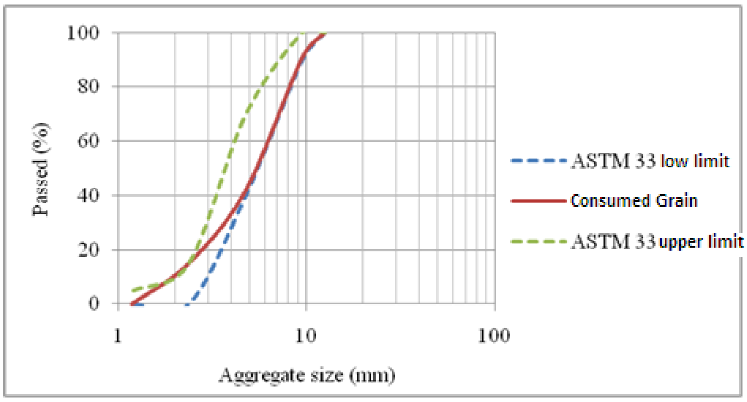

Fig. 1: Grading Curve of Grain.

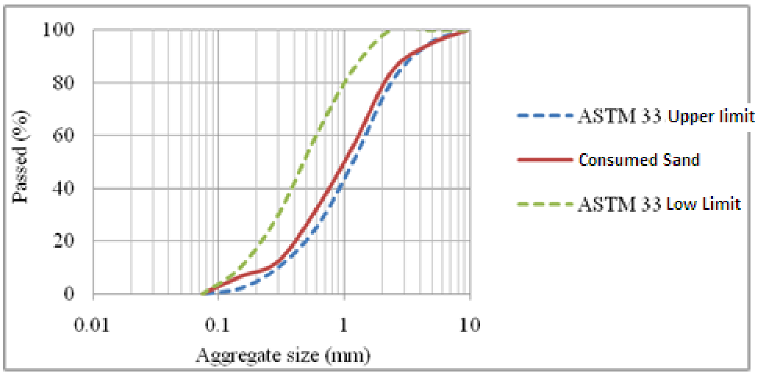

Fig. 2: Grading Curve of Sand.

3.3. Cement

Portland cement used in this study, is type-2 production at factory of Zarand Saveh cement that contains weight for 3150 kg/m^3 and special level 290 m^2 /kg.

3.4. Zeolite

Natural zeolite used in this research has been extracted from mines in Semnan province. Chemical and mineral compounds are according to below table.

Table 1: Chemical and Mineral Compounds of Zeolite

Mineral compositions (%)		Chemical analysis (%)	
70.6	clinoptilolite	1.68	Calcium oxide
18.8	opal CT	67.79	silica
1.6	Quartz	13.66	Alumina
2.4	plagioclase	1.44	Iron oxide
1.5	K-feldspar	1.2	Magnesium oxide
5.2	clay minerals	2.04	sodium oxide
		1.42	potassium oxide
		0.52	sulfur trioxide

Fig. 3: Consumed Zeolite.

4. Mixing portions

In the first phase, in addition to control concrete which was prepared without zeolite, 4 mixing plan containing different percent of zeolite (5%, 10%, 15% and 20% zeolite) with water to cement of 0.45 was prepared.

Table 2: Concrete Mix Design of Specimens

water-cement ratio	Zeolite percent-age	Grain	Sand 0-3	Sand 3-6	water	Cement	ze-olite	super plasti-cizer
w/c = 0.45	control concrete	921	694	173	180	400	0	1.25
	Ze 5%	921	694	173	180	380	20	2
	Ze 10%	921	694	173	180	360	40	3
	Ze 15%	921	694	173	180	340	60	4
	Ze 20%	921	694	173	180	320	80	5.75

5. Results

To study the engineering behavior of zeolite-containing concrete, standard tests of compressive strength and ultrasonic wave velocity (UPV) was used.

5.1. Compressive strength test results

Compression strength tests were performed after storing in humid conditions at ages 7, 28 and 90 days. The results of the compressive strength for the control concrete and concrete specimens containing different percent of zeolite at normal temperature are presented.

As can be seen from the results, replacement of cement with different percentages of zeolite (i.e. 5%, 10% and 15%) would increase compressive strength at normal temperature in all ages. values of increase at mentioned percentages for the age of 7 days, is respectively, 2%, 7.9%; 4.08% and at age 28 days is 3%, 16%, 3.8%. finally at age of 90 days it is 5%, 19.7%, 8.47%. however, replacement 20% zeolite caused decrease at compressive strength which amounts for ages 7, 28 and 90 days, respectively for 15.5%, 1.92% and 7.38%.

5.2. The effect of temperature on compressive strength

To evaluate the effect of temperature on the compressive strength of concrete, cube samples with dimensions of 100 millimeter were imposed to increasing temperature. Thermal changes contains 200, 400 600 ° c. the compressive strength test results, is the average result of three samples. The results of testing the compressive strength against a rise in temperature for every five mix are shown at age 90 days.

5.3. Results for ultrasonic waves speed

measuring the velocity of ultrasonic waves was performed on concretes containing different percentages of zeolite at ages 7, 28 and 90 days, at normal temperature and as well as next after heat given to samples at specified temperatures at age 90 day using Pundit instrument (with frequency of 54 kHz). This test is used to collect information of density and uniformity of concrete samples.

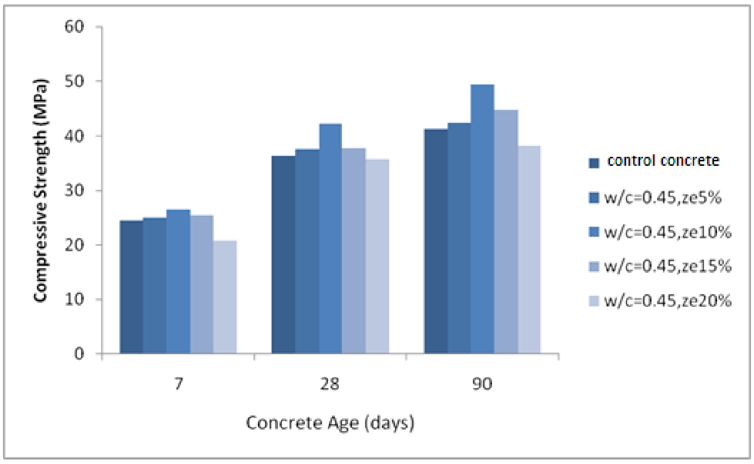

Fig. 4: Comparison of the Concrete Compressive Strength for Concrete Containing Different Percentages of Zeolite and Control Specimens.

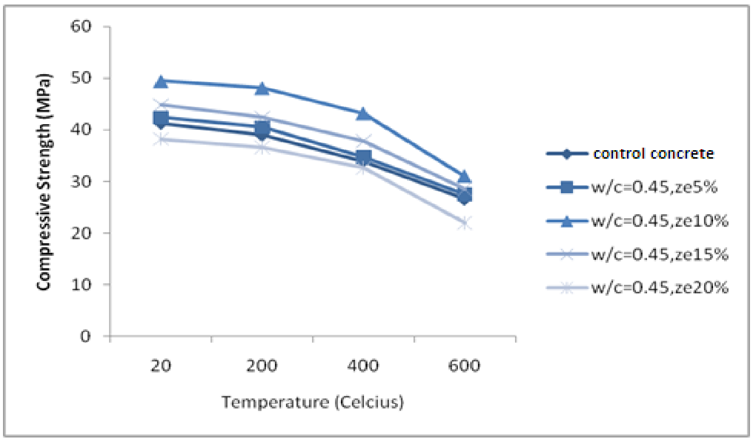

Fig. 5: Compressive Strength against Temperature Rise in Concrete Containing Different Percentages of Zeolite.

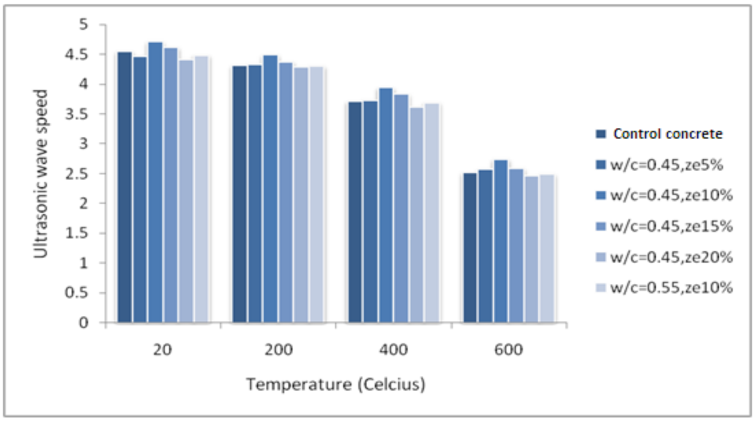

Fig. 6: Comparison of the Velocity of Ultrasonic Waves at Different Ages at Various Temperatures.

From the results it is concluded that the velocity of ultrasonic waves decreases with increasing temperature. The reason for this decrease is that in the range of 100 up to 200 degree of centigrade free water at concrete starts to evaporate and causes pressurized steam. This pressure inside concrete makes a network of micro cracks. on continue, at range 200 up to 400 ^{0c} the micro cracks convert into larger cracks and ultrasonic waves slow down more. At 400 up to 600 degree of centigrade speed of ultrasonic waves reduces significantly, for the reason that cement paste and calcium hydroxide would decompose.

6. Conclusion

Based on the experiments the final conclusions are made as below:

1) According to the comparison of results including 5 mixtures containing different amounts of zeolite and water-cement ratio of 0.45 it is concluded that replacement level of 10% of cement with zeolite at ratio water to cement of 0.45 at ages 7, 28 and 90 day, is the optimized replacement level to zeolite.
2) Ultrasonic waves are enhanced in all mixing portions, confirming that increases of concrete age directly rises up the compressive strength of specimens.

Compressive strength of all specimens has decreased after exposure to temperatures of 200, 400 and 600 degree of centigrade. The reduction in the temperature range of 20 up to 200 is of less value, and happens due to the evaporation of free water in the concrete in the range of 100 up to 200 and creation of a network of micro-cracks in the concrete. On continue, this process in temperature range of 200 up to 400, the micro cracks in the concrete convert to larger ones, as well as the larger structure and diameter of pore reduces the compressive strength of concrete further. From 400 up to 600 degrees of Celsius, the excessive reduction of compressive strength observed resulting from chemical decompositions.

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