Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(4) (2021) 381-384
DOI: 10.22060/ceej.2020.17090.6458

Evaluation of Natural Zeolite Effect on the Mechanical Properties of Concrete Containing Coarse Masonry Recycled Aggregates

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ABSTRACT: The present investigation has studied the effect of the replacement of different percentages of natural zeolite (Ze) pozzolan powder on the mechanical properties of recycled concrete made from coarse masonry recycled aggregates. In made concretes, natural aggregates were replaced with recycled coarse masonry aggregates at 25%, 50%, and 100% levels. To improve the mechanical properties, natural zeolite was replaced by cement at 10%, 20%, and 30% levels. In total, 195 standard cubic and cylindrical concrete samples in the 16 mixing designs were made and compressive strength tests at 7, 28, and 91 days, splitting tensile strength, modulus of elasticity, and ultrasonic pulse velocity at 28 days of age was evaluated. the results showed that at replacement levels of 20% natural zeolite with cement was had the greatest improvement in the mechanical properties of natural concrete but in combination with recycled aggregates, the replacement of 10% natural zeolite by cement was improved the mechanical properties of recycled concrete. Also. the results showed that 10% of natural zeolite, using up to 50% of coarse masonry recycled aggregates, Improvement some mechanical properties of recycled concrete was showed relative to conventional concrete without pozzolan, but replace 100% coarse natural aggregates with recycled masonry, mechanical properties of recycled concrete have significantly decreased compared to natural concrete without pozzolan.

Review History:

Received: 2019-09-21
Revised: 2020-01-20
Accepted: 2020-04-05
Available Online: 2020-05-07

Keywords:

Recycled Concrete
Coarse Masonry Recycled Aggregates
Mechanical Properties
Natural Zeolite Pozzolan Powder

1. Introduction

Today, it is no secret that the rapid development of infrastructure in developing countries has led to much environmental damage. Concrete is one of the products that have a great role in consuming non-renewable resources. Today, the view based on sustainable development in the manufacturing industry is growing and increasing, and concrete as one of the most widely used construction products is at the forefront of this view. It is estimated that waste from construction and demolition will account for about 40% of total waste [1]. Production of construction waste in the United States has reached about 140 million tons, and the European Union has announced the production of construction waste per year is 970 million tons, equivalent to 2 tons per citizen [2]. According to the European Union, about (50-55) % of construction waste is concrete waste, and about (30-40) % of this waste is construction waste and a small percentage includes other waste such as glass and wood [3]. Therefore, many of these countries have defined one of the foundations of sustainable development in the reuse of recycled aggregates. Leite showed that the aggregates obtained from the construction and demolition were suitable for the construction of concrete [4]. It is estimated that by 2020, at least 50% of the construction materials for new buildings will be recycled materials [5]. Because (60-75) % of the volume of concrete aggregates [6] and due to the feasibility of recycling construction waste, as well as it's environmental, and economic benefits, waste recycling construction and demolition work as a new source of concrete aggregates has attracted much attention [7]. However, some regulations have chosen caution in the use of recycled aggregates, especially in the use of structures, due to the unknown nature of some of their long-term behaviors [8, 9]. Some regulations, such as the UK and German standards, have restricted their use [10, 11], but engineering societies are still working to provide a platform for the use of these concretes for public use. One of the main problems of this type of concrete is the significant reduction of its mechanical properties in alternatives above 30% [12, 13]. However, some studies have shown that it is possible to achieve higher strength than conventional concrete in replacing 50%, and it is also possible to achieve the design strength required to replace up to 100% [14]. Although the use of pozzolanic materials such as fly ash and micro-silica as admixtures in concrete is common, the effects of using natural zeolite as a pozzolanic material, especially in the production of recycled concrete, have been less studied. In one study, the effect of natural zeolite on the performance of self-compacting concrete (SCC) was investigated. The results

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Table 1. Chemical Compounds of Cement Materials Used in Research (%)

Cement materials	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	LOI
Cement	19.8	3.9	3.1	65.3	2.5	2.8	2.2
Ze	68	1.5	11.5	2.5	-	-	12.2

of the experiments showed that natural zeolite improves the performance of SCC in the fresh state. Natural zeolite increases the viscosity and stability of concrete and reduces bleeding, and in severe cases, results in compressive strength equal to or greater than that of reference concrete [15]. This study examines the effect of different percentages of replacement of "coarse masonry aggregates" along with the effect of using natural zeolite on the mechanical properties of recycled concrete made from this type of aggregates.

2. Research methodology

2-1- Cement materials used in research

The chemical composition of the cementitious materials used in research is presented in Table 1.

2-2- How to prepare coarse recycled masonry aggregates

Coarse recycled masonry aggregates included broken bricks, cement plasters, stone, tiles, and ceramics, which were obtained from destroyed buildings in Ahvaz. Initially, construction debris was collected from different depots in the required amount, and then their waste, including soil, plaster, glass, and metals, was separated. With the help of a grinder machine, all debris was shredded and granulated after sieving. The resulting recycled aggregates, which were granulated based on the Iranian National Concrete Mixing Plan, had an MSA of 19 mm, a water absorption rate of 15.22% by weight, and a dry density of 1.04 tons/m3 in the furnace. Ahvaz drinking water was used in the construction of concrete mixtures as well as the curing of samples. Polycarboxylate-based SP with commercial abbreviation POWER PLAST-PM and a density of 1.1+/-0.02 g/cm3 were used.

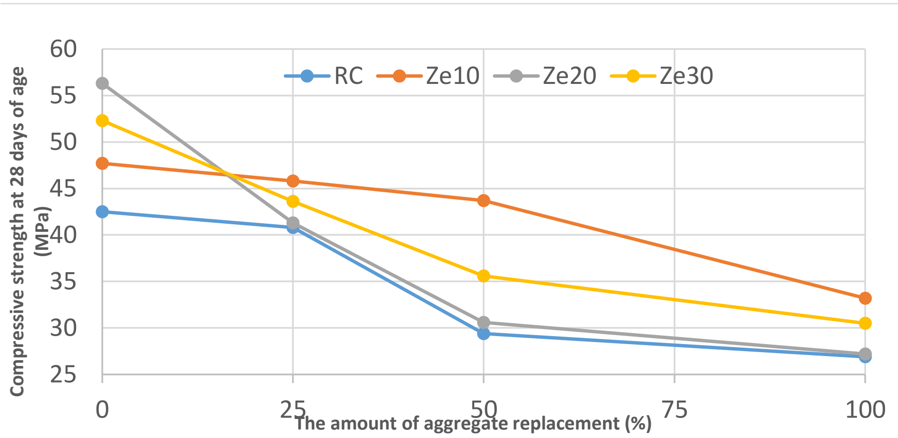

Fig. 1. Compressive strength changes at 28 days of age according to the percentage of aggregate replacement for ordinary and recycled concrete containing natural zeolite

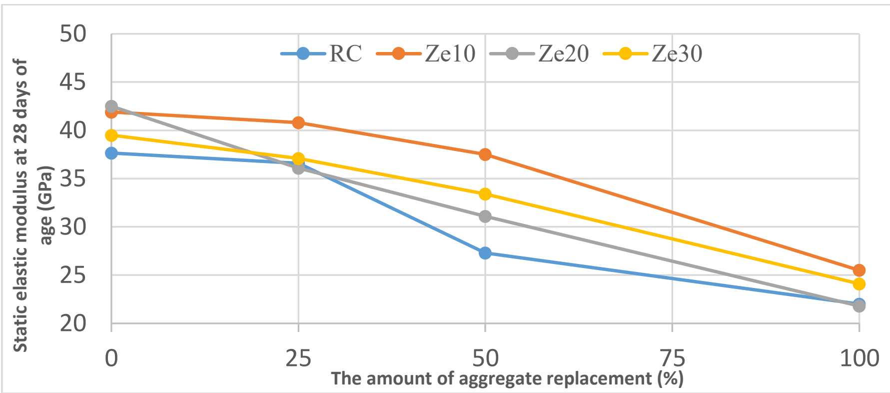

Fig. 2. Static elastic modulus changes at 28 days of age in percentage of aggregate replacement for conventional and recycled concrete containing natural zeolite

Table 2. Details of the mix design of research concrete (kg/m^3)

MD	C	NZe	W	SP	S	NG	RG
RC0/CC	420	4.2	150	-	-	937	766
RC25	420	4.2	150	-	234	703	766
RC50	420	4.2	150	-	468.5	468.5	766
RC100	420	4.2	150	-	937	-	766
RC0-Ze10	399	4.2	150	42	-	937	766
RC25- Ze10	399	4.2	150	42	234	703	766
RC50- Ze10	399	4.2	150	42	468.5	468.5	766
RC100- Ze10	399	4.2	150	42	937	-	766
RC0- Ze20	378	4.2	150	84	-	937	766
RC25- Ze20	378	4.2	150	84	234	703	766
RC50- Ze20	378	4.2	150	84	468.5	468.5	766
RC100- Ze20	378	4.2	150	84	937	-	766
RC0- Ze30	357	4.2	150	126	-	937	766
RC25- Ze30	357	4.2	150	126	234	703	766
RC50- Ze30	357	4.2	150	126	468.5	468.5	766
RC100- Ze30	357	4.2	150	126	937	-	766
MD: mix design, C: cement, NZe: natural zeolite, W: water, SP: super-plasticizer, S: sand, NG: natural gravel, RG: recycled gravel							

2-3- Research mix design

Sixteen mixing designs were built with different percentages of coarse recycled masonry aggregates and natural zeolite pozzolan. In all designs, the water to cement ratio is 0.36 and the amount of cement is 420 kg/m3. The process of mixing materials is based on the three-stage mixing process provided by Sajedi and Jalilifar [16]. The details of the mixing scheme used in the study are presented in Table 2.

3-Results and discussion

3-1- Compressive strength at 28 days of age

3-2- Static elastic modulus at 28 days of age

4. Conclusions

The key results of the research are as follows:

- Consumption of 20% and 30% of natural zeolite in natural concrete, has caused the compressive strength of concrete to exceed 50 MPa.

- All recycled concrete with 25% coarse recycled masonry materials and containing natural zeolite, reached the characteristic strength of 40 MPa within 28 days, and in 50% replacement of recycled materials, only concrete containing 10% natural zeolite achieved the characteristic strength of 40 MPa.

- In the replacement percentages of 25% and 50% of the coarse recycled masonry aggregates and in all the replacement percentages of natural zeolite, the concretes were in the range of “good quality level”.

- Replacing 100% of natural aggregates with coarse recycled masonry aggregates has left all concrete in a “weak and suspicious quality level”.

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HOW TO CITE THIS ARTICLE:

M. Azhdarizadeh, S. F. Sajedi, Evaluation of Natural Zeolite Effect on the Mechanical Properties of Concrete Containing Coarse Masonry Recycled Aggregates, Amirkabir J. Civil Eng., 53(4) (2021): 381-384.

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