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Investigation of the technical and economic desirability of recycled concretes containing pozzolan

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ABSTRACT: The present paper investigates the effect of the replacement of recycled concrete aggregates (RCA's) on the mechanical properties and durability of RC's and their technical and economic desirability. Concretes made to replace RA's including 25%, 50% and 100% were made. To improve the quality of RC's, micro-silica, fly ash and natural zeolite pozzolans were replaced separately with partial cement. A total of 40 mixing designs were made in the form of 1000 standard concrete specimens. In a period of 28 days, tests of compressive strength, splitting tensile strength, static elasticity modulus and ultra-pulse velocity (UPV) and in a period of 180 days, tests of immersion water absorption (IWA), capillary water absorption (CWA), electrical resistivity, electrical conductivity and rapid chloride penetration (RCPT) was applied to the specimens. It was concluded that even with the replacement of pozzolanic materials, the results of IWA and CWA conditions in RC's are affected by the development of porous and capillary space due to increased replacement of RCA's. From the viewpoint of the results related to electrical resistivity, electrical conductivity and RCPT, due to changes in the chemical structure of the pore flow in RC's, it is possible to achieve RC's with similar durability to ordinary concrete. The desirability of RC's made from both technical and economic perspectives and their interaction were examined. Among the concretes made, 25% RC's containing 10% and 15% micro-silica and 10% natural zeolite and 50% RC containing 10% micro-silica showed more technical and economic desirability than reference concrete.

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1- Introduction

The rapid advancement and development of technology in the world require the upgrading of infrastructure, and this is done directly by human encroachment on environmental resources and upsetting the balance of the environment. The need to develop new infrastructure and the inefficiency of existing infrastructure have made the exit of existing infrastructure out of the operational cycle inevitable. Preservation of existing environmental resources requires the development of a vision based on sustainable development in the construction industry. The construction industry alone is responsible for consuming more than 50% of natural resources, 40% of energy and producing 50% of the world's waste [1]. Recycling materials from the destruction of infrastructure is one of the approaches that different countries use as one of the active options. The rate of this process in some developed countries such as Japan, Germany and the Netherlands reaches 80% and in some other developed countries in the range of (20-40)% [2]. In contrast, developing countries have a very small part of this global approach. For example, while the per capita daily production of waste in Tehran is almost twice as high as the global average, a very small portion of this waste re-enters the recycling cycle [3]. Excessive consumption of concrete as one of the main components of the construction process on the one hand and the need for excessive use of natural aggregates and the limited space of the depot of degraded materials, on the other hand, has led to the approach of aggregate production recycling of degraded materials should be given more attention.

Since, compared to the mechanical properties of recycled concrete, fewer studies have been conducted on the durability of this concrete in Iran, this article aims to identify these properties of recycled concrete to measure some important and effective properties in the durability of this concrete. Therefore, by combining 4 replacement levels of coarse recycled aggregates along with 3 replacement levels of pozzolanic materials, it resulted in the production of 40 different mixing designs. After introducing the special mixing method related to recycled aggregates in this research, 28-day compressive strength (CS) tests, 28-day halving tensile strength, 28-day static elasticity coefficient, 28-day ultrasound propagation velocity, immersion water

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Table 1. Chemical composition of cementitious materials used in research

LOI	SO_3	MgO	CaO	Al_2O_3	Fe_2O_3	SiO_2	
2.2	2.13	1.2	64.34	6.1	3.7	21.28	cement
12.2	-	-	2.5	11.5	1.5	68.0	Natural zeolite
-	0.1	0.97	0.49	1.23	0.87	94.73	Silica fume
3.7	0.68	5.2	2.8	28.2	5.3	56.7	Fly ash

Table 2. Physical characteristics of cementitious materials used in research

Average particle size (Micrometers)	**Specific surface area (m^2/kg)**	**Specific density (g/cm^3)**	
26.0	295	3.15	cement
16.8	320	2.20	Natural zeolite
0.15	20000	2.26	Silica fume
37.9	440	2.30	Fly ash

Table 3. Details of the proportions of mixtures used in the research

Recycled gravel	Natural gravel	Sand	Superp-lasticizer	water/binder ratio	Water	Cementitious materials	Mixed design
(kg)	(kg)	(kg)	(lit)	---	(lit)	(kg)	
0.0	815	888	4.2	0.36	150	420	CC
204.0	611						RC25
407.5	407.5						RC50
815.0	-						RC100

absorption and capillary water absorption 180 Fasting, 180-day electrical resistivity, 180-day electrical conductivity, and 180-day accelerated chloride ion diffusion were performed. After studying and comparing the simultaneous effect of the replacement of recycled concrete coarse aggregates and pozzolanic materials on mechanical properties and properties related to the durability of recycled concrete, to select the desirability of the designed designs, the interaction of economic and technical desirability of each design compared to conventional concrete were investigated.

2- Experimental program

2- 1- the materials used in the research

The chemical composition and physical characteristics of the cementitious materials used in the research are presented in Tables 1 and 2.

2- 2- Aggregates

To ensure the same effect of natural and recycled aggregates, recycled aggregates were made exactly like natural aggregates. Details of the proportions of mixtures for making ordinary concrete, recycled concrete containing 25%, 50% and 100% of recycled aggregates are presented in Table 3.

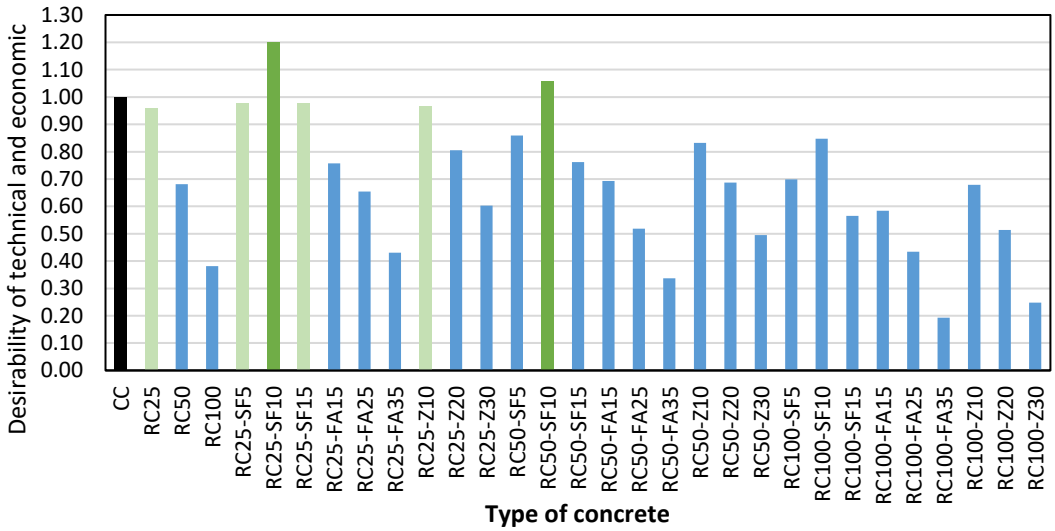

Fig. 1. Technical-economic desirability of research concretes in comparison with reference concrete

3- Results and Discussion

The technical-economic desirability of research designs compared to the reference design is shown in Figure 1.

4- Conclusions

The key results of the research are as follows:

-CS in the complete replacement of aggregates was reduced by 18% compared to reference concrete; while the replacement of 25% of recycled aggregates did not result in a significant change in CS.

-All recycled concretes containing microsilica (SF) reached a target strength of 40 MPa. The results showed that in the replacement of 10% SF, it is possible to achieve higher CS than the reference concrete.

-The absorption rate of immersion water in 25% recycled concrete without pozzolan remained unchanged compared to reference concrete and in 100% recycled concrete increased to 87% and reached 9.12%. At the most desirable replacement levels for pozzolanic materials, none of the 50% and 100% recycled concretes had lower immersion water absorption than the reference concrete.

-Substitution of pozzolanic materials showed that using these materials as a substitute for cement, cannot reduce the destructive effect of increasing the replacement of recycled aggregates in increasing capillary water absorption.

-Based on the electrical resistivity test results, the possibility of corrosion in fully recycled concrete was confirmed.

-The electrical resistivity is more affected by the internal chemical changes of the concrete and the changes in the pore flow in the cavities inside the concrete than by the porous structure of the recycled concrete.

-By increasing the replacement from 25% to 100% of recycled aggregates, the electrical conductivity increased compared to the reference concrete in the range of (17-67)%; However, the effect of pozzolanic materials in improving the quality of recycled concretes was such that it was possible to achieve 100% recycled concrete with an electrical conductivity lower than the reference concrete.

-The results showed that in comparison with reference concrete, concretes with 25% and 50% of recycled aggregates and containing 10% SF, have more technical-economic benefits than reference concrete.

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