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An Investigation of RPC containing Recycled Metal Spring and its Comparison with the Concrete including Steel Fibers Exposed to the Acidic Environment

G. Pachideh[1], M. Gholhaki[1*], A. Moshtagh[2]
[1] Department of Civil Engineering, Semnan University, Semnan, Iran
[2] Department of Civil Engineering, Garmsar University, Garmsar, Iran

ABSTRACT: Reactive Powder Concrete (RPC) is a developing composite cementitious material that will allow the concrete industry to optimize material use, generate economic benefits and build structures that are robust, durable and environmentally friendly. This paper deals with the performance of reactive powder concrete (RPC) containing recycled metal spring and its comparison with that of including steel fibers exposed to the acidic environments. To this end, several specimens were built in 10×20 cm^2 metal cylindrical formworks in ambient temperature (around 25°c) containing 0.3 and 0.6% of steel fibers and recycled metal spring in concrete volume, respectively so as to conduct the tensile and compressive strength tests in compliance with ASTM C39. Subsequently, the specimens were cured in an environment with magnesium sulfate content of 0, 5 and 10% within 28 days. Based on the results, the addition of recycled metal spring and steel fibers to the RPC managed to improve the compressive and tensile strengths by 50 to 60%. Moreover, the specimens containing recycled spring better withstood against the acidic environments in comparison with the specimens, including steel fibers. In general, it was found that due to the negligible difference between the strength of the specimens, application of metal recycled spring in reactive powder concrete is technically and economically justifiable.

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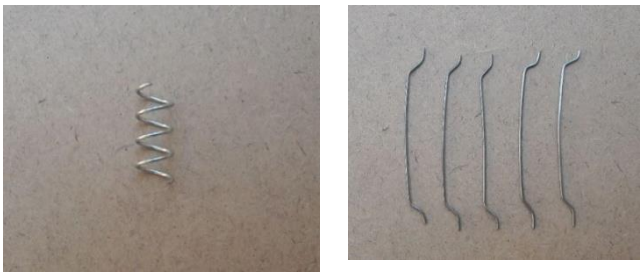
1. INTRODUCTION

Reactive Powder Concrete (RPC) is a developing cementitious composite material which enables the practitioners to optimize material use, generate economic benefits, and build structures that are robust, durable, and sensitive to the environment. This material is one of the primary and major ingredients of ultra-high-performance concretes (UHPC) [1]. Great strength and rupture capacity together with considerable durability, are regarded as the particular characteristics of the reactive powder concrete [2-5].

Accordingly, Anand and Abraham carried out a study on the effect of adding polyester fibers on the physical properties of reactive powder concrete. Based on the results of tests performed on the reactive powder concrete with a grade of 90 MPa, the durability-related properties were improved, whereas the other mechanical properties were degraded [6].

2. METHODOLOGY

To determine the compressive and tensile strength, 126 cylindrical specimens containing 0.3 and 0.6% of recycled metal spring and steel fibers were built and tested after being placed in an acidic environment taking in 0, 5, and 10% of magnesium sulfate. Due to the previously conducted tests, if the spring content exceeds 0.6%, the springs will be most likely interwoven, and the aggregates will not be able to be densely spaced. Therefore, the use of spring greater than 0.6% is not recommended.



a) Metal Spring **b) Steel Fibres**

Fig. 1. Image of Fibres and Spring

Figure 1 shows the image of the recycled metal spring and steel fibers used in this study.

The springs used in this study were made out of low-carbon steel (galvanized steel) provided by recycling the springs utilized in the stationary. The cross-section area of the springs is circular, with diameter and density of 0.8 mm and 7860 kg/m3, respectively. It is noteworthy that the properties of galvanized steel including thermal resistance, modulus of elasticity, and density are quite the same as those of ST37 steel, and their behavior is somehow similar.

The amount of all materials used for concrete construction is presented in Table 1 based on the cement's weight as well as

*Corresponding author's email: mgholhaki@semnan.ac.ir

Table 1. Mix Designs Characteristics

Design Name							Concrete Volumetric Percentage	
	Cement	Water	Silica Powder	Silica Sand	Silica Fume	superplasticizer	Recycled metal spring	Steel Fiber
A	840	180	178	924	202	39.480	0	0
SF1	840	180	178	924	202	39.480	0	0.3
SF2	840	180	178	924	202	39.480	0	0.3
8SP1	840	180	178	924	202	39.480	0.3	0
8SP2	840	180	178	924	202	39.480	0.6	0
12SP1	840	180	178	924	202	39.480	0.3	0
12SP2	840	180	178	924	202	39.480	0.6	0

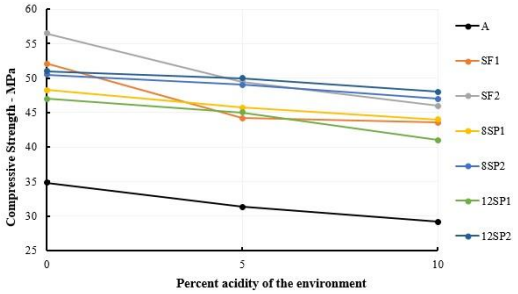


Fig. 2. Compressive Strength of the Specimens exposed to the Acidic Environments

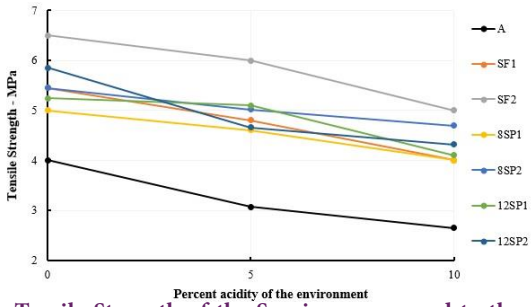


Fig. 3. Tensile Strength of the Specimens exposed to the Acidic Environments

the volumetric percentage of fibers and spring. To reduce the water content and improve the workability of concrete, poly-carboxylate superplasticizer was utilized. All stages of mixing, construction, and curing of the specimens were accomplished in the Concrete Technology Laboratory of Semnan University.

To build the reactive powder concrete, first, the silica powder and silica sand are mixed in the mixer in a dry state. Then, one-third of water and superplasticizer were added to the mixture and mixed for one minute. After that, half of cement and silica fume and water, as well as the cementitious materials and superplasticizer are added to the mixture and mixed for three minutes. Lastly, the spring and fibers were added to the mixture.

3. RESULTS AND DISCUSSION

To evaluate and compare the performance of specimens containing fibers and spring exposed to the acidic environments, the results are cumulatively presented in Figures 2 and 3. As shown in Figure 2, in the case of the non-acidic environment (acidic content of 0%), the specimens containing steel fibers experience a greater compressive strength compared to the other specimens. However, as the specimens are placed in an acidic environment with 5% of acidity, the specimens containing steel fibers are degraded more intensively with a steeper slope compared to the other specimens which are attributed to the greater potential of steel fibers against corrosion in comparison with that of the galvanized recycled steel spring. Accordingly, despite significant improvement in the compressive strength of the concrete gained by adding spring and fibers, it is found that recycled springs are both economically and technically more justifiable. Moreover, the same trend for tensile strength is seen in Figure 3.

4. CONCLUSIONS

- It was found that addition of metal spring with diameters of 8 and 12 mm (8SP-12SP) as well as the steel fibers to the reactive powder concrete exposed to the non-acidic environment (i.e., 0% of acidic effects), enhances the compressive strength of concrete by 1.62, 1.45 and 1.47 times greater than that of the reference specimen.

- Addition of metal spring and steel fibers to the reactive powder concrete exposed to the 5 and 10% acidic environment, managed to improve the compressive strength by 1.5 and 1.6 times greater compared to that of the reference specimen in a way that as the amount of magnesium sulfate rates up in the curing environment, the strength of specimens containing spring raises greater than that of the specimens including steel fibers. Furthermore, as the acid content grows, the loss of compressive strength of the specimens containing spring is rather less than that of the specimens taking in fibers such that this loss is approximately 3 and 12% in the specimens containing spring and fibers, respectively.

- The tensile strength of the specimens containing steel fibers and metal spring with a diameter of 8 and 12 mm in the non-acidic environment (i.e. 0% of sulfate magnesium) was observed to be 1.62, 136 and 1.46 times greater than that of the reference specimen. However, due to the insignificant difference between the growth rate of strengths, it is technically and economically more justifiable to apply spring, especially in the coastal and industrial areas suffering from severe corrosivity.

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