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Saša Stojadinović

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INFLUENCE OF SILICA FUME ON SCC CONCRETE PROPERTIES

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Abstract
The use of recycled materials or waste increases sustainability in the construction sector. Likewise, the self-compacting concrete (SCC) has shown improvement in mechanical properties, when made with some waste pozzolanic materials. The differences in the compressive strength of the SCC concrete sample in the case of 5% by mass share of silica fume compared to samples with 7% were explored. The results shown that optimal replacement of Ordinary Portland Cement by silica fume is 5%, under applied experimental conditions.

Keywords*: sustainability, recycling, compressive strength.*

1. INTRODUCTION

The durability of concrete can be improved by limiting size and type of aggregate, the w/c ratio, and also by the usage of pozzolanic materials like: silica fume, nano-silica, fly-ash, blast furnace slag, etc. [1]. On the other hand, the use of recycled materials or waste increases sustainability in the construction sector [2]. Substitution of Ordinary Portland Cement (OPC) by waste pozzolanic materials in concrete also increases the energy efficiency of the processes involved.

Silica fume represents a by-product from the exhaust gases of ferrosilicon, silicon, and metal alloys smelting furnaces [1]. Silica fume addition in concrete might refine pore structure which leads to improvement in permeability and durability of concrete. By the utilization of optimum dosage of silica fume, a significant increase in strengths could be achieved. A concrete of high durability can be developed using fine ground pozzolanic admixture silica fume [3]. The better performance of concrete could be attributed to the fact that it exhibits lesser micro cracking and dense microstructure due to silica fume and calcined clays as pozzolans for concrete [4].

Also, the self-compacting concrete (SCC) has revealed improvement inmechanical properties made by using silica fume [5]. Due to the higher fineness of silica fume, it reacts very fastwith some hydration products of cement and thereby reducesthe porosity of concrete, hence resulting in improvement ofmechanical and durability properties of the concrete. In the earlystages, silica fume remains an inert material in concrete. Thehydration of cement produces C-S-H (Calcium Silicate Hydrate)and calcium hydroxide (free lime). C-S-H isresponsible for strength. The pozzolanic action takes placebetween calcium hydroxide and silica fume, which further producesadditional C-S-H in the voids left after hydration of cement.The extra C-S-H improves mechanical and durability properties by providing a much denser matrix [6].

According to the literature data, the author's opinions are divided regarding the participation of silica fume. By some authors, the optimized dosage of silica fume lies in 7 – 10 or 8–10% share of cement (by weight) [7]. However, some investigation showed that the optimal rate of silica fume in concrete is 5%. It is observed that the optimum dose of silica fume is 5% when used as a partial replacement of OPC. The silica fume inclusion increases the workability and strength of concrete considerably[8].

The aim of this study was to investigate the effect of reducing the recommended silica fume dose in SCC with recycled aggregate. The differences in the compressive strength of SCC concrete in the case of a 5% share of silica fume compared to samples with 7% were explored.

2. EXPERIMENTAL

Materials of sampleswere:

- Silica fume (0.1µm average particle size);
- OPC, PC35 M (V-L) 42.5 R,Beočin, Serbia;
- Limestone filler, Granit peščar, Ljig, Serbia;
- Superplasticizer, TKK, Slovenia;
- Aggregate, Gradient, Serbia;
- Recycled aggregate, smashed experimental samples;
- Water.

Namely, all samples had to achieve values of slump flowmore than 800 mm according to recommendations [9], therefore a required amount of superplasticizer was used.

The defined compositions of the SCC samples are listed in Table 1.

Table 1 –Compositions of the samples

Materials	Amounts	
	SCC7	SCC5
OPC	353.4 kg/m^3	368.6* kg/m^3
Limestone filler	223 kg/m^3	223 kg/m^3
Superplasticizer	1.1%	1.1%
Water	178 kg/m^3	178 kg/m^3
Aggregate (I, II, and III faction)	860; 265; 155 kg/m^3	860; 265; 155 kg/m^3
Recycled aggregate (I, II, and III faction)	0; 265; 155 kg/m^3	0; 265; 155 kg/m^3
Silica fume	7%	5%

*OPC mass was increased due to the reduced mass of silica fume

The extremely fine, amorphous, and latently reactive silica fume was used. Before water addition, silica fume was mixed with OPC. The optimal mixing time was 90 s.

Dry materials, i.e. recycled aggregate, limestone filler, and cement/silica fume mixture were mixed for one minute. Water was added for the next 30 s, after which the superplasticizer was dosed with the addition of water. Stirring was continued until 5 min. had elapsed. The samples were demolded after 1 day andcured in 20˚C water for 28 and 90 days (in total).

3. RESULTS AND DISCUSSION

The compressive strength tests were performed according to the standard SRPS EN 12390-3:2010 for cubic samples [10].

The results are presented in Figure 1. for SCC7 and SCC5 samples after 28 and 90 days marked as SCC7-28, SCC5-28, SCC7-90, and SCC5-90, respectively.

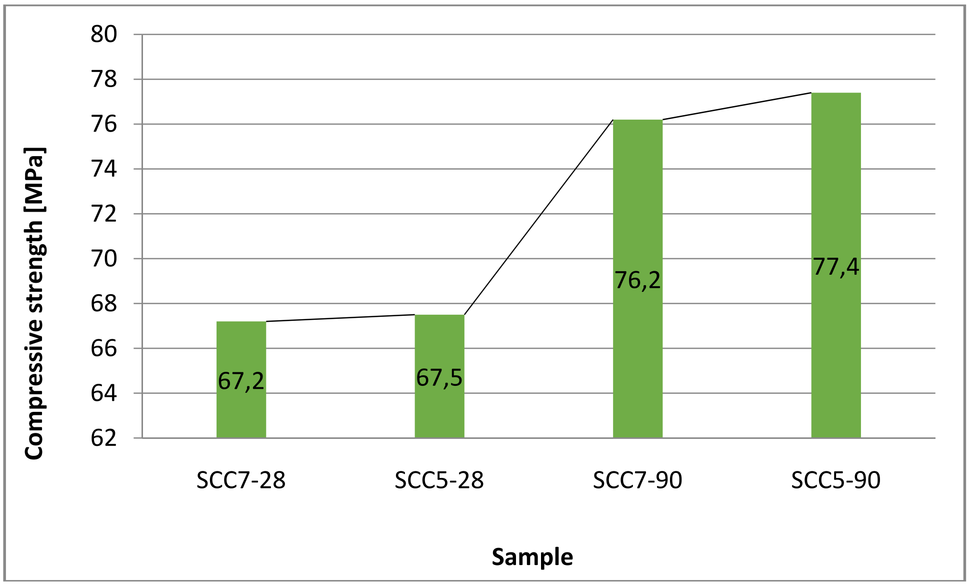

Figure 1. Compressive strengths of samples

The results showed that the compressive strength after 28 days was not significantly affected by the reduction in the amount of silicate fume. However, measurements after 90 days indicated that the sample with 5% silica fume (SCC5-90) showed slightly higher compressive strength.

Based on the results, it could be noted that the improvement in compressive strength due to silica fume incorporation in concrete occurs because of the chemical pozzolanic activity and filler action. However, an increase in thecompressive strength in SCC5 samplescould be explained by silica fume higher amount in SCC7than it was requiredfor pozzolanic actions, and hence reduction in strength [8].Likewise, the amount of OPC in SCC5 samples was higher relative to SCC7, and compressive strength was expected to be elevated. This investigation indicated that the optimal replacement of OPC by silica fume is 5%, under applied experimental conditions.

4. CONCLUSION

The effect of the recommended silica fume amount reduction in SCC with recycled aggregate was explored. The compressive strength of samples after 28 and 90 days were performed. The results for samples SCC7-28, SCC5-28, SCC7-90, and SCC5-90, were 67.2, 67.5, 76.2, and 77.4 MPa, respectively. An increase in compressive strength in samples with 5% silica fume could be explained by silica fume higher amount in SCC7 than it was required for pozzolanic actions and a higher amount of OPC.

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