THE INFLUENCE OF NANOSILCA ON MECHANICAL PROPERTIES OF HIGH STRENGTH CONCRETE

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UDK: 666.982.24
DOI:10.14415/konferencijaGFS 2016.039
Summary: A large number of studies throughout the world deals with producing material which has a significantly improved properties compared to conventional materials. The application of nanosilica is one of the possibilities for obtaining high strength concrete. This paper shows the influence of nanosilica and steel fibers on the mechanical properties of concrete. The results of testing concrete without and with the addition of 2% of nanosilica and with the addition of 0, 2 and 4% of steel fibers, with non-destructive and destructive methods, were compared.

Keywords: *high strength concrete, nanosilica, steel fibers*

1. INTRODUCTION

For the last few years, the use of non-destructive methods for diagnostics and defectoscopy of the state of the structure has been increased. The great advantage of non-destructive methods, despite the fact that they do not damage or only cause minor surface damage, is the simplicity of the testing. The most demanding task in modern construction is the interpretation of the obtained results. [1,2].
The relations between the compressive strength of concrete (destructive method) and the values measured by using non-destructive methods are known for ordinary concrete, but it has been observed that these relations do not apply to high strength concrete, which are composed of modern materials.
Concrete as a composite material has extremely heterogeneous properties. Variations in strength, modulus of elasticity and in all other properties need to be observed by the content of individual components of concrete in total volume. The evaluation of the modulus of elasticity of concrete is possible by the means of two-phase models

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consisting of cement stone and aggregate. It is necessary to know their modulus of elasticity and the percent of aggregate in the concrete volume.

There are several basic models that show concrete as a two-phase composite composed of aggregate and cement paste or coarse aggregate and mortar [3]. For example Voigt and Reuse models which assume a uniform deformation or equal straining between the two phases in concrete, so they are observed in parallel or serial configuration [3]. Hirsch model of elastic behavior of composite materials introduces empirical constant x which denotes the relative share of parallel or serial model, and is used to explore the relations between the cement paste and aggregate [3].

Hansen model consists of spherical aggregate placed in the center of a spherical matrix, and similar to it is the Count model in which the prism of aggregate is located in the center of the matrix prism [3]. None of these models take into account the impact of voids and cracks in concrete, changes in phase state (e.g. due to freezing of water in concrete), specific geometric functions of phases, interaction of pores and aggregates under different load conditions and the influence of particle shape of aggregate, which is very important in the case of different modulus of elasticity. For this reason, some authors (Nielsen, Monteiro) proposed a model with three phases, i.e. also introduced the transition zone in concrete into the model - a transit zone [3]. Hashin and Monteiro developed a mathematical model based on the assumption that concrete is a composite that consists of a matrix in which spherical elements are embedded, each surrounded by a concentric spherical shell - the so-called interphase [3]. Some sophisticated models (e.g. Mori - Tanaka) also take into account the impact of pores and cracks in concrete [3]. Thus, the properties of concrete in hardened state depend on several different parameters, that is, not only on the share of components in concrete composition, but also on the conditions of compacting, care and exposure of concrete element to influences from the environment. The evaluation of the properties of hardened concrete and their non-destructive testing methods in the construction is particularly difficult in the case of special types of concrete, such as, for example, high strength concrete.

2. EXPERIMENTAL WORK

The aim of this study is to investigate the possibility of application and impact of nanosilica in high strength concrete. Two groups of concrete were made. The first group consists of concrete without nanosilica, with the addition of 0, 2% and 4% of fibers. The second group was made with the addition of 2% of nano-silica with the addition of 0, 2 and 4 % of steel fibers. Test results for high strength concrete obtained by non-destructive and destructive methods are shown.

Nanoparticles have a high surface area to volume ratio (Fig. 1) which provides high chemical reactivity. Nanosilica (nano-SiO2), and nano-titanium oxide (nano-TiO2) are used in most investigations, while nano-Fe2O3 is used in a few of them [4].

2.1. Design of high performance concrete

The design of ultra high performance concrete is different than that of ordinary concrete. A high amount of fine particles is used for HPC manufacturing. Their chemical and mineral properties are shown in Table 1.

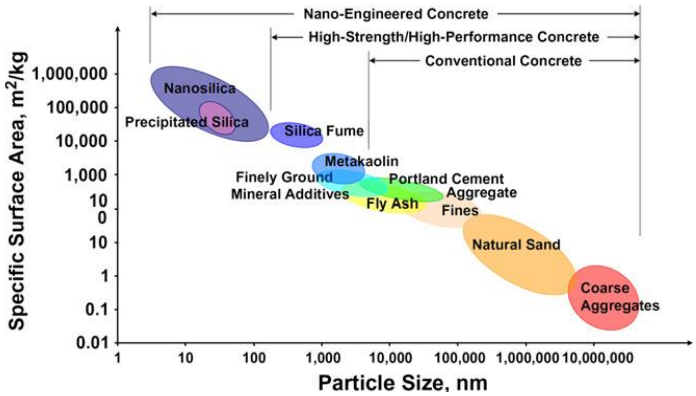

Figure 1. Particle size and specific surface area related to concrete materials [4]

Table 1. Composition of powder materials and sand (%)

	Cement	Silica fume	Quartz powder	Quartz sand
SiO_2	20.51	92.52	97.54	97.54
Al_2O_3	6.15	0.64	0.52	0.52
Fe_2O_3	2.80	0.31	0.57	0.57
CaO	63.41	0.38	0	0
MgO	1.85	0.44	0	0
Na_2O	0.29	0.32	0	0
K_2O	0.79	0.87	0.24	0.24
SO_3	2.69	0.22	0	0

Concrete was made with ordinary Portland cement CEM I 42.5 R. Also, silica fume (SF) and nano-silica (nS) with average particle size of 7 nm were pozzolanic materials. Quartz powder (Qp) with average particle size of 50 µm and quartz sand (Qs) were used as aggregate. A modified polycarboxylates based superplasticizer allowed high water reduction. Brass coated steel fibers with 8 mm length and a diameter of 0.15 mm were used (2 and 4% by volume).

Six types of concrete were made with a varying percent of nano-silica (0%, 2% and 4%) and aggregate type (quartz and barite). Compositions of concrete mixtures are shown in Table 2.

Table 2. Concrete mixture composition (kg/m^3)

	C	SF	nS	Qp	Qs	Water	Superpla -sticizer	Fibers
K0f0	950	200	0	350	635	235	55	0
K0f2	950	200	0	350	600	235	55	155
K0f4	950	200	0	350	550	235	55	310
K2f0	950	200	19	350	635	240	55	0
K2f2	950	200	19	350	600	240	55	155
K2f4	950	200	19	350	550	240	55	310

2.2. Results of concrete testing

2.2.1. Compressive strength

Samples for testing compressive strength of concrete were made. Concrete was compacted on the vibrating table in cube shaped metal molds, edge d = 100 mm, which were cured in water at a temperature of + 20 ° C until the moment of the testing according to SRPS EN 12390-2 standard. Testing of compressive strength of concrete at the age of 7 and 28 days was carried out according to SRPS EN 12390-3 standard. The test results are shown in Table 3 below.

Table 3: Compressive strength of high strength concrete

Mix N°	Compressive strength N/mm^2	
	7 dana	28 dana
K0f0	88.0	106.0
K0f2	91.8	112.3
K0f4	100.1	126.8
K2f0	90.2	108.4
K2f2	94.5	114.2
K2f4	103.4	130.5

2.2.2. Non-destructive method of testing – testing the velocity of ultrasonic impulse

Testing with a non-destructive method is mainly performed for quality control of concrete production or quality control of concrete on the construction site, and very often for the assessment of the state of existing structures as well as for the evaluation of the quality of the works performed on the repairs of buildings. Generally, when using non-destructive methods it is not possible to directly obtain the data about the strength of the material, but for a proper assessment of the strength it is necessary to know the relations between the test results by non-destructive methods and compressive strength determined by destructive testing. Although numerous methods for non-destructive testing of concrete were developed, sclerometer and ultrasound tests are usually performed. [1,2].

Table 4. Determination of ultrasonic pulse velocity

Mix N°	Pulse velocity m/s
K0f0	3922
K0f2	3883
K0f4	3846
K2f0	3810
K2f2	3774
K2f4	3738

Measurements by non-destructive method using ultrasonic pulse according to the SRPS EN 12504-4 method were performed. The method is based on measuring the travel time of longitudinal ultrasonic waves through a concrete sample.
Measurements were carried out on concrete prism shaped samples with the dimensions of 10x10x40 cm which were cured and sampled in the same way as other tests. The test results are shown in Table 4.

2.2.3. Static modulus of elasticity of concrete

Samples for testing static modulus of elasticity were made. The samples are cylinder shaped with the dimensions ø /h=15/30cm. The testing was performed according to the SRPS ISO 6784 method. The results of the measurement are shown in Table 5.

Table 5. Static modulus of elasticity

Mix N°	Static modulus of elasticity GPa
K0f0	42.5
K0f2	45.0
K0f4	46.0
K2f0	41.0
K2f2	45.0
K2f4	45.5

3. CONCLUSION

Based on the obtained test results it can be concluded that for concrete made with the same amount of fibers compressive strength increased up to 3% for samples made with nanosilica. By increasing the amount of fibers to 4% compressive strength increases by 20% compared to the reference concrete.
Ultrasonic pulse velocity shows that the concrete has a homogeneous composition. In both types of concrete, with and without nanosilica, the same effect was established, that is, by increasing the amount of fibers the velocity of the ultrasound is reduced.
In both types of concrete, with and without nanosilica, by increasing the amount of fibers the static modulus of elasticity is also increased.

ACKNOWLEDGMENTS

The work reported in this paper is a part of the investigation within the research project TR 36017 "Utilization of by-products and recycled waste materials in concrete composites in the scope of sustainable construction development in Serbia: investigation and environmental assessment of possible applications", supported by the Ministry of Education, Science and Technology, Republic of Serbia. This support is gratefully acknowledged.

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UTICAJ NANOSILIKE NA MEHANIČKA SVOJSTVA BETONA VISOKIH ČVRSTOĆA

Rezime: Veliki broj istraživanja u svetu se bavi dobijanjem materijala koji ima znatno poboljšana svojstva u odnosu na konvencionalne matererijale. Primena nanosilike je jedna od mogućnosti za dobijanje betona visokih čvrstoća. U ovom radu je prikazano istrživanje uticaj nanosilike i čeličnih vlakana na mehanička svojstva betona. Upoređivani su rezultati ispitivanja betona bez i sa dodatkom 2% nanosilike i dodatkom čeličnih vlakana od 0, 2 i 4%, nedestruktivnim i destruktivnim metodama.

Ključne reči: *beton visokih čvrstoća, nanosilika, čelična vlakna*