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COMBINED EFFECT OF NANO SILICA AND NANO ALUMINA ON THE MECHANICAL PROPERTIES OF HPC

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Abstract

This paper details experimental investigations into how nano silica and nano alumina affect the mechanical properties of high-performance concrete. In order to reduce the amount of cement needed, mineral admixtures such as nano silica, nano alumina, and micro silica are used. High performance concrete's compression strength, split tensile strength, and flexural strength have all been studied. Nano silica is added to concrete at a rate of 3% by weight of cement, nano alumina is set at 1% after trials, and micro silica is set at 10%. Mechanical properties were found to be significantly enhanced by the addition of both nano silica and nano alumina, as compared to the control mix. The addition of nanoparticles to concrete enhanced its mechanical properties by increasing its consistency and decreasing its porosity.

Key words: High performance concrete, Micro silica, *Nano-Silica, Nano-Alumina, Nano-Iron oxide, Nano-titanium oxide, Nano carbon tubes*

Introduction

Due to its high strength and durability, high performance concrete is commonly used in constructing long-lasting structures like skyscrapers, bridges, and tunnels. Many investigations are being carried out to find alternate cementitious materials to cement, such as fly ash, GGBS, micro silica, etc. Nanomaterials have recently seen widespread application across a range of industries. There are alternative materials to cement that, like nanomaterials, provide improved properties.

Compressive strength was found to increase by 20% after 28 days when an optimal content of 3% nano silica was used (Mukharjee & Barai, 2014). The experimental investigation of nano silica's behaviour as a partial replacement of cement (Sakthivel, R., & Balasundaram, D. N. (2016)) found that compressive strength increased by 26% at 3% replacement of nano silica. The addition of nano alumina to mortars has been shown to increase compactness in the interfacial transition zone and improve the porosity of cement paste (Li et al., 2006). Nano silica's effect on high performance concrete was studied by Vivek et al. in 2020, and the results showed that, at 3% replacement, nano silica increased the mechanical properties of concrete and had a positive effect on pore filling. Nano silica, nano alumina, and nano titania were all tested for their individual and combined effects on the properties of self-compacting mortars (Mohseni et al., 2015). In terms of compressive strength, he found that NST and NSA

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performed better in binary mixes, while NA and NS each performed better at 1%, 3%, and 5% concentrations.
The effects of NS and NA on the mechanical properties of high-performance concrete after 28 and 90 days were investigated in this paper. These properties included the compressive strength, split tensile strength, flexural strength, and non-destructive test results from the USPV.

Experimental work

Materials

Cement "confirming to IS 12269 - 1987" (KCP) grade 53 OPC was used. Cement has a specific gravity of 3.10, a fineness of 6%, and a consistency of 34%.
The fine aggregate was a locally sourced river sand with a fineness modulus of 2.59 and a specific gravity of 2.65. Coarse aggregate was composed of crushed stone with a maximum particle size of 20 mm and a specific gravity of 2.6. The 1.1 specific gravity admixture is BASF master ease 3709 super plasticizer.
Xetex Industries Private Limited's 25-micron micro silica was used for this. Table 1 demonstrates the characteristics of micro silica.
Nano silica from astrra chemicals in Chennai, India, with a particle size of 17 nm, was used in this experiment without any modification. In table 2 you can see some of the characteristics of nano silica.
The 20-nanometer nano-alumina supplied by the India-based krishti artize and technik company was used. Table 3 shows the nano alumina properties.

Table 1
Properties of Micro silica.

S. no.	Properties	Test result
1	SiO_2 (%)	92.24
2	CaO (%)	0.63
3	Al_2O_3 (%)	0.39
4	Fe_2O_3 (%)	0.24
5	MgO (%)	0.75
6	TiO_2 (%)	-
7	Specific gravity	2.11
8	Particle size	25 microns
9	Loss on Ignition at 1000 °C (%)	3.95

Table 2
Properties of nano silica.

S. no.	Property	Test result
1	SiO_2 (%)	99.88
2	Al_2O_3 (%)	0.005
3	Fe_2O_3 (%)	0.001
4	TiO_2 (%)	0.004
5	Specific gravity	2.2 – 2.4
6	Particle size	17 nm
7	Loss on Ignition at 1000°C (%)	0.66
8	pH	4.12
9	Tamped Density	44

Table 3
Properties of Nano alumina.

S. no.	Property	Test result
1	SiO_2 (%)	0.05
2	CaO (%)	0.02
3	Al_2O_3 (%)	99.8
4	Fe_2O_3 (%)	0.04
5	MgO (%)	0.03
6	TiO_2 (%)	0.02
7	Particle size	20 nm
8	Loss on Ignition at 1000°C (%)	10
9	pH	4.5
10	Tamped Density	50

Mix design

Two high performance series mixes were prepared. Based on trials in the laboratory we obtained best blended mix. Micro silica fixed at 10%, nano silica fixed at 3% and nano alumina after trails we obtained 1%. M_1 series mixtures are designed as control mix, which is made up of cement, there are three main components of aggregate: fine aggregate, coarse aggregate, and water. The other one named as NSA mixture prepared with different proportions of nano silica (3%), nano alumina (1%) and micro silica (10%) replacement by weight of cement. Water to binder ratio was fixed at 0.21. mix proportions details are given in table 5.

Table 5
Mix proportions.

S.No	Properties	M_1	NSA
1	Cement (kg/m3)	550	475
2	Fine aggregate (kg/m3)	555	555
3	Coarse aggregate (kg/m3	1146	1146
4	Water cement ratio	0.21	0.21
5	Micro silica (kg/m3)	-	55
6	Nano silica (kg/m3)	-	15
7	Nano alumina (kg/m3)	-	4.8
8	Super plasticizer %	0.25	2%

Testing of specimens

Compressive strength, split tensile strength, and flexural strength were all determined by testing specimens that were cubes (150 mm), cylinders (150 mm), and beams (100 mm x 100 mm x 500 mm) in size. According to IS 516, tests of compressive strength, split tensile strength, and flexural strength were conducted. Three samples from each test were cast and monitored for 28 and 90 days. Each test was conducted on three separate samples, and the average of these values is presented. Ultrasonic pulse velocity non-destructive testing was carried out on a PROCEQ-supplied 150 mm x 150 mm x 150 mm cube. As a result of testing on three different samples, an average value was provided.

Results and discussion

Fresh concrete properties

Slump values were drastically cut with the addition of nano silica and nano alumina. As their size is reduced, their specific surface area increases, making them more effective. When NS and NA absorb the water, slump disappears. Nanoparticles like nano silica and nano alumina are so reactive that they attract water and form chemical bonds with it. Because of this, less water is available for the mixing process. This is why nano silica and nano alumina impair the workability of concrete. When compared to control mix slump values reduced significantly for blended concrete. However, using admixtures can improve the slump value significantly. In this project BASF master ease 3709 was used and workability of concrete has improved. Overall, the slump value for control mix is around 110 mm and slump values for nano concrete after using admixture is observed around 40 – 50 mm. we can still improve the workability by increasing the percentage of admixture to be added but we need to be cautious whether it is showing any adverse effects on strength and durability properties.

Compressive strength

Compressive strength of cube specimens made from control mix (M_1) and concrete with nano particles is displayed in Fig. 1. (NSA). It is widely observed that cube specimens of concrete with nano silica, nano alumina, and micro silica added have greater compressive strength than control mix. An ultimate compressive strength of 118.25 MPa was attained by NSA after 90 days. At 28 days, the compressive strength of the NSA mix was found to be higher than that of the M1 mix by 24.7%. While M_1 mix's compressive strength increased by 2% at 90 days, NSA's did so by a significantly larger 17.6%.

Nano silica and nano alumina have very high specific surface area due to their less size, making the concrete dense by reducing the voids. The addition of water initiates a chemical reaction between nano silica and nano alumina. The Ca (OH)2 is decreased and the C-S-H gel is increased by the addition of nano silica and nano alumina. This is the primary reason why the strength of concrete has been growing over time.

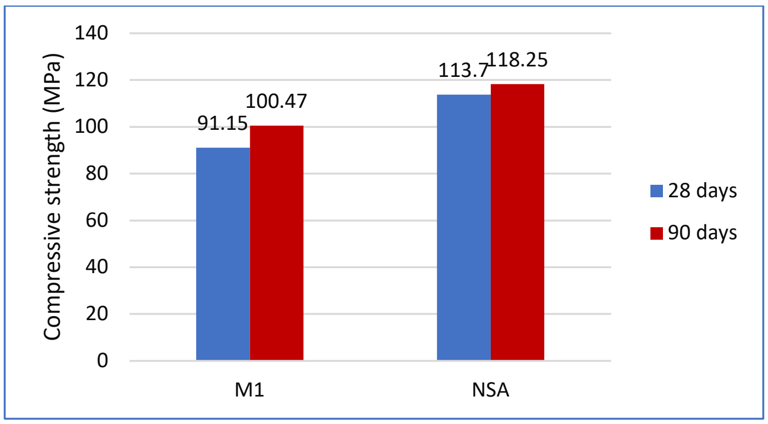

Fig 1 Compressive strength of concrete specimens

Split tensile strength

Figure 2 shows how the split tensile strength of both the standard (M1) and the experimental (M2) mixes vary over time (NSA). When compared to the control mix, the addition of nano particles increases the split tensile strength. Maximum split tensile strength of 11.47 ksi was attained after 90 days, as shown in fig. 2. The split tensile strength of M1 and NSA is 8.34 MPa and 10.78 MPa after 28 days and 9.38 MPa and 11.47 MPa after 90 days, respectively. The split tensile strength of NSA mix was higher than that of M1 mix by 29.2 percent at 28 days and 22.3 percent at 90 days.

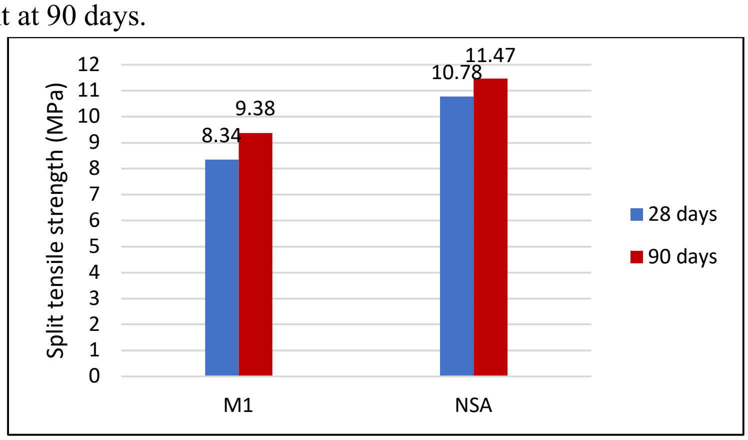

Fig 2. Split tensile strength of concrete specimens

Flexural strength

Figure 3 shows the flexural strength of M1 and NSA concrete mixes at 28 and 90 days. The flexural strength was enhanced by the addition of NS and NA. At age 28 the flexural strength of M1 and NSA mix was 8.91 MPa and 12.01 MPa, respectively; at age 90, these values increased to 10.07 MPa and 12.64 MPa, respectively. There was a 34.7% increase in flexural strength at 28 days for the NSA mix and a 25.7% increase by 90 days compared to the control mix.

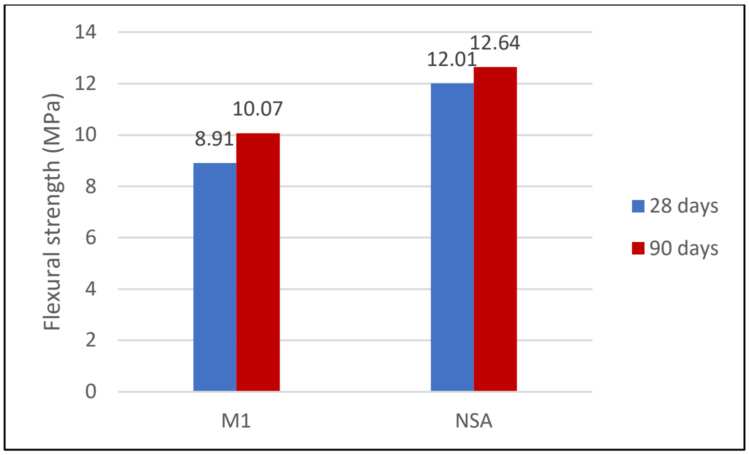

Fig. 3 Flexural strength

USPV test

The main purpose of an ultrasonic pulse velocity test is to ascertain the quality of concrete in relation to the presence of cracks, pores, and other modifications to the concrete's microstructure. Cubes specimens are used before testing for compressive strength. USPV values ranges from 4854 m/s to 5335 m/s. USPV test values for 28 days and 90 days are shown in fig. 4. When compared with control mix concrete including nano particles shown better results.

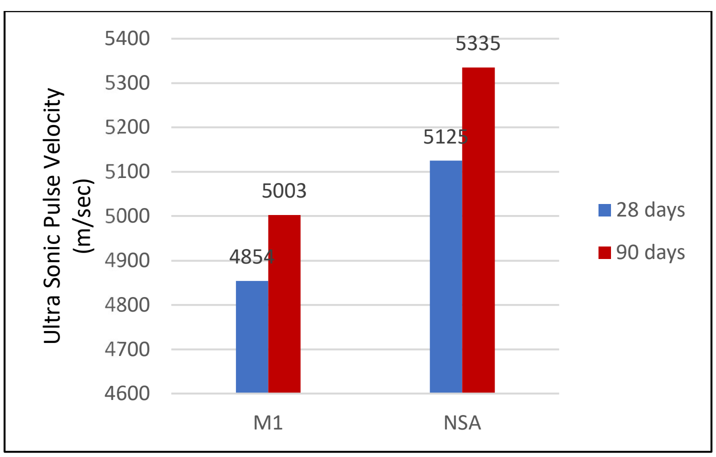

Fig. 4 Ultrasonic pulse velocity values in m/sec

Conclusions

The following conclusions can be drawn from the above results

1. Use of combined effect of nano silica and nano alumina improved the mechanical properties significantly.
2. Adding nano silica and nano alumina decreased the workability significantly. To improve the workability low water cement ratio admixture should be used.
3. When compared to control mix concrete incorporating nano silica and nano alumina showed higher compressive strength. Compressive strength increased by 24.7% and 17.6% at 28 and 90 days respectively for NSA mix.
4. Split tensile strength increased by 29.2% and 22.3% at 28 days and 90 days respectively for NSA mix when compared with M_1 mix
5. Flexural strength improved by 34.7% and 25.7% at 28 days and 90 days.

Reasonable guidance on the ideal concrete mix proportion can be provided for real practice. However, extensive studies should be done before real practice of nano concrete.

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