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EFFECT OF NANO SILICA ON PROPERTIES OF CONCRETE

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Abstract

This study presents experimentally the collective consequence of using nano silica (NS) on mechanical properties of tough concrete. NS is cast-off as partial cement substitution by 1,1.5,2 wt% . Mechanical properties of hardened concrete are assessed expending different mixtures between NS. Important enhancement in the mechanical properties of concrete is experiential with NS due to its high pozzolanic activity approving the creation of advanced quantity of C–S–H gel in the existence of nanoparticles. Employing 2 wt% NS due to to improves properties of hardened concrete in increasing compressive strength, splitting strength, modulus of elasticity and flexural strength compared to samples without either NS.
Keywords: Nano Silica, Steel Fiber, Splitting Strength, Compressive Strength, Flexural Strength, Modulus of Elasticity.

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Introduction

Many investigators involved in assess the consequence of using Nano Silica (NS) on physical, durability of concrete and mechanical properties. nano materials no performance only as pozzolanic improver but too as fillers developing the pore structure of concrete and densifying the microstructure of cement paste [1– 6].

The mechanical behavior of concrete materials depends to a excessive amount on structural elements and phenomena which are active on a micro- and nano scale. The aptitude to board material alteration at the nano structural level promises to deliver the optimization of material performance and act wanted to advance expressively the mechanical show, volume change properties, durability, and sustainability of concrete. This synopsis is inscribed to contribution in the identification of hopeful new investigation and innovations in concrete materials using nanotechnology that can effect in enhanced mechanical properties, volume change properties, durability, and sustainability. The mechanical behavior of concrete materials depends to a great extent on structural elements and phenomena that are effective on a micro- and nanoscale. The size of the calcium silicate hydrate (C-S-H) phase, the main constituent accountable for strength and other properties in cementitious systems, lies in the few nanometers range. The structure of C-S-H is much like clay, with thin layers of solids separated by gel pores filled with interlayer and adsorbed water. Hence, nanotechnology may have the potential to engineer concrete with superior properties concluded the optimization of material behavior and show required to suggestively develop mechanical act, durability, and sustainability.

The quantity of C–S–H gel is improved due to high pozzolanic achievement of fine particles and also mineral admixtures with fine particles can increase the filler result. Microstructure in the interfacial transition zones enhanced with low water cement ratio [7]. Nano silica, due to its high unusual surface, is expressively reactive [8], and products C-S-H reduced gel as a product of reaction with CH.

Compressive strengths of hardened cement paste and bond strengths of paste–aggregate are improved by including NS, and NS can advance the interface structure more efficiently than incorporating silica fume [9]. Filler consequence of fine nanoparticles developed the rheological properties by increasing nanoparticles percentage [10].

Adding of variable ratios of nano-silica expressively enhanced the overall show of concrete [11]. The attendance of steel fibers at several volume fractions give great improvement in compressive strength, splitting tensile strength and modulus of rupture of high strength concrete [12].

The durability and mechanical properties of self-compacting cement are meaningfully enhanced with using both Nano Silica and fibers in best percentages; however toughness is reduced by increase Nano Silica more than 2 wt% [13].

In this study several mechanical properties of concrete are explored and estimated experimentally by using different combinations of nano silica and steel fibers in concrete to attain concrete with high characteristics compared with normal concrete.

2. MATERIAL AND METHODS

2.1 Cement

the main cementing material used in this study is Ordinary portland cement (OPC). It submits with the Iraqi Standard Specification [14] as received from the companies, the cement is Iraqi ordinary Portland cement (Taasluja) Type (I). The general chemical properties of the OPC is exemplified in table 1.

2.2 SiO2 nanoparticles

Nano SiO_2 (NS) with regular particle size about (9 to 20) nm is cast-off as recognized from physical laboratory at housing and building national research centre . XRD test shows the amorphous structure of NS (exemplified in Fig. 1). As it shown, the XRD patterns illustration an about broad peak centered 2ɵ ≈ 22° which demonstrates the amorphous structure of utilized NS [1].

2.3 Aggregates

Two kinds of aggregates are used in the concrete mixture: fine and coarse aggregates. Fine aggregates are locally offered natural sand. Fine aggregates pass from 4.75 mm (No. 4) sieve and retain in 75 lm (No. 200)sieve [15]. particle size of Coarse aggregates not exceed 14 mm.

2.5 Superplasticizer

A high performance concrete superplasticizer based on polycarboxylic technology. Glenium 51 primarily developed for requests in the premixed and precast concrete businesses where performance and the highest durability is required. Glenium 51 is free chlorides and complies by ASTM C494 type a [1]. Table (2) demonstrations the properties of Glenium 51[16].

2.6 Mix proportioning

A overall of twenty mixtures are prepared in the laboratory. Device mix is primed by NS or SF, additional mixtures are organized using NS as partial cement replacement by 1, 1.5, 2wt%, the mixtures proportions are presented in Table (3).

2.7 Mixing process and Treatment

Nano Silica is practical for 10 minutes of ultra-sonication investigation to be vibrated in very high speed to avoid collection and more effective in dissolving NS shown in Fig. 4.

The dry materials are first mixed without using fibers to avoid fiber balling for 1min at little speed to reach a homogenous mixture, after that wet varied at low speed for additional minute, then colloidal NS is additional to avoid any agglomeration which might happened and finally (SF,SP) are added and mixed at intermediate speed to 3 minutes, therefore respectable workability concrete of uniform material is created [12].

Once the mixing procedure is concluded, the samples are located into molds and reserved under laboratory condition for 24 h. They were then removed from the molds and kept in 22–25 °C water until the suitable age for each investigate. All mixing design contains three 150 mm diameter cylinders molds with 300 mm height for splitting test.

2.8 Test methods

Split tensile test was approved out in agreement with the ASTM C 496 [16] standard. After curing period was over, the concrete cylinders were exposed to split tensile test by using universal testing machine. Tests were approved out on triplicate specimens and average split tensile strength values were achieved. ASTM C 469 [17] for the static modulus of elasticity. Experienced samplings are showing to uniaxial compression capacity expending universal testing machine. After 28 days of curing determined the stress-strain features. Flexural tests are achieved in agreement with the ASTM C293 [18] . Established specimens are showing at mid-span to one point load. Then, flexural tests are approved out on triplicate samples and average flexural strength values are achieved.

Concrete mix design in this study uses the w/c = 0.38. The composition of the concrete mixtures is given in table (3).

Table 1: Chemical composition of OPC (wt%).

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	L.
O.I Cement	21	4.04	3.01	62.235	1.66	3.34	0.46	4.05	0.37

Table (2): Properties of Glenium51

Form	Viscous Liquid
Commercial name	Glenium 51
Chemical composition	Sulphonated melamine and naphthaline formaldehyde condensates
Subsidiary effect	Increased early and ultimate compressive strength
Form	Viscous liquid
Color	Light brown
Relative density	1.1 gm/cm³at 20 °C
pH	6.6
Viscosity	128 ± 30 cps @ 20° C
Transport	Not classified as dangerous
Labeling	No hazard label required
Chloride content	None

Table 3: Mixture proportions of NS blended concretes.

Mix symbol	NS (%)	Cement (kg/m³)	Nanosilica (kg/m³)	Water (kg/m³)	Sand (kg/m³)	Gravel (kg/m³)	Superplasticizer (kg/m³)
NC	0	450	0	175	675	1115	9
NS1	1	445.5	4.5	175	675	1115	9
NS2	1.5	443.25	6.75	175	675	1115	9
NS3	2	441	9	175	675	1115	9

3. Mechanical Properties of Hardened

Control samples are cast from the same mixtures used for the SCC beams. Four mechanical properties are assessed here: compressive strength (f'c) , modulus of rupture (fr), splitting tensile strength(ft) and modulus of elasticity(Ec). Three samples used for each test of any stuff and the average value of the three results are adopted, the results are shown in table (4).

Table (4): Properties of Concrete at 28 days

Mix symbol	Compressive strength (MPa)		Fr (MPa)	ft (MPa)	Ec (GPa)
	Cube 150x150 Fcu	Cylinder 150x300 f_c'			
NC	68.23	55.34	7.60	5.29	35.121
NS1	88.15	70.45	8.44	6.12	40.389
NS2	98.17	78.88	9.45	6.51	42.496
NS3	104.34	83.47	9.58	6.69	43.198

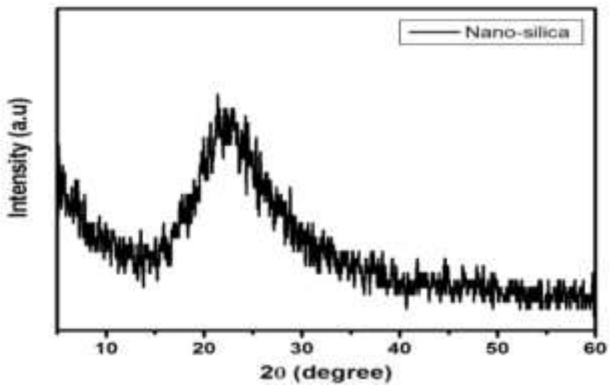

Figure 1. XRD of SiO2 nanoparticles with particle size of (9-20) nm.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Compressive Strength

The compressive strength test, as presented in figure (2) was determined according to BS 1881: part 116[21], using Cubes of (150×150×150) mm tested by a hydraulic compression machine of (2000) kN. The SCC samples were cast without compaction. Using three specimens as average testing is taken, Test was conducted at ages 28 days.

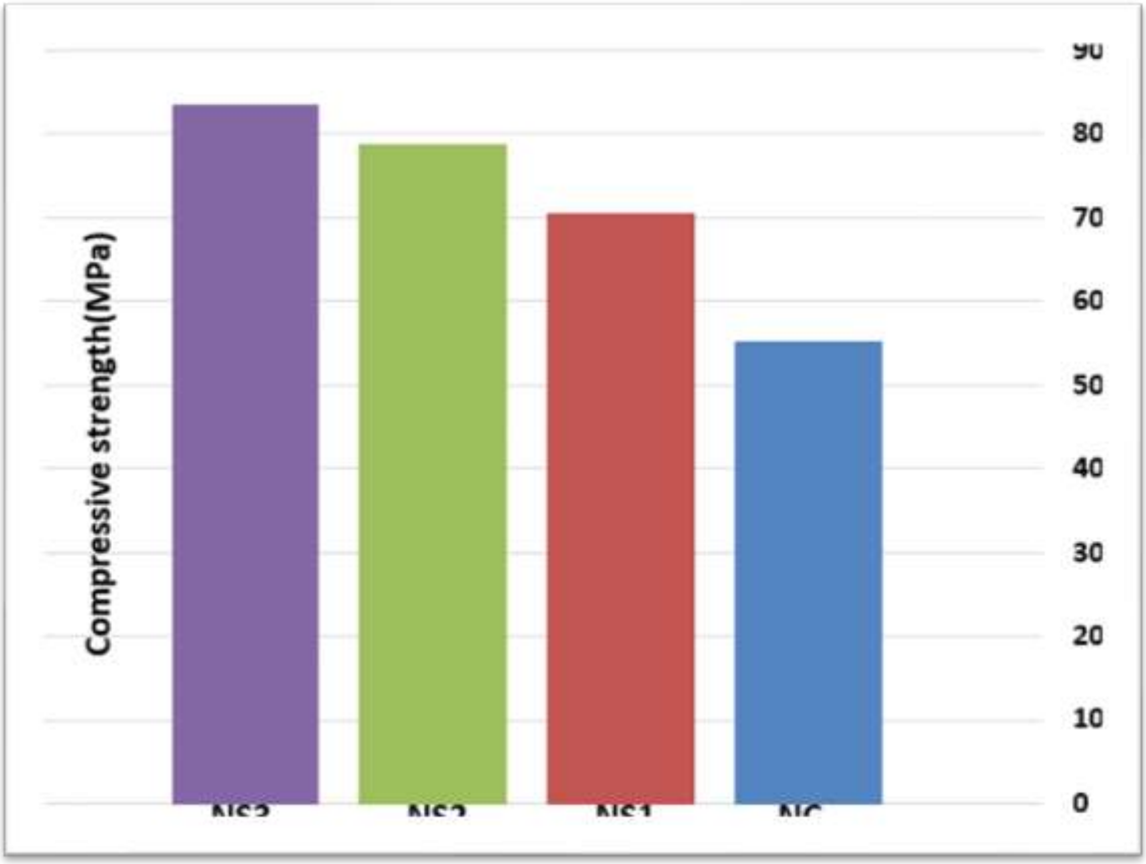

Figure (2): Compressive strength

3.2 Flexural strength

The regular experiment effects of flexure strength of SF and SiO_2 nanoparticles concretes for each mix is offered in Fig. 3. It is originate that rise in the quantity of SF enhanced the flexural strength. Flexural strength test (modulus of rupture) is carried out by using (100 x 100 x 500 mm) prisms, by using hydraulic machine of 2000 kN capacity. According to ASTM C78-02 [22],by three concrete prisms and take the average of three results.

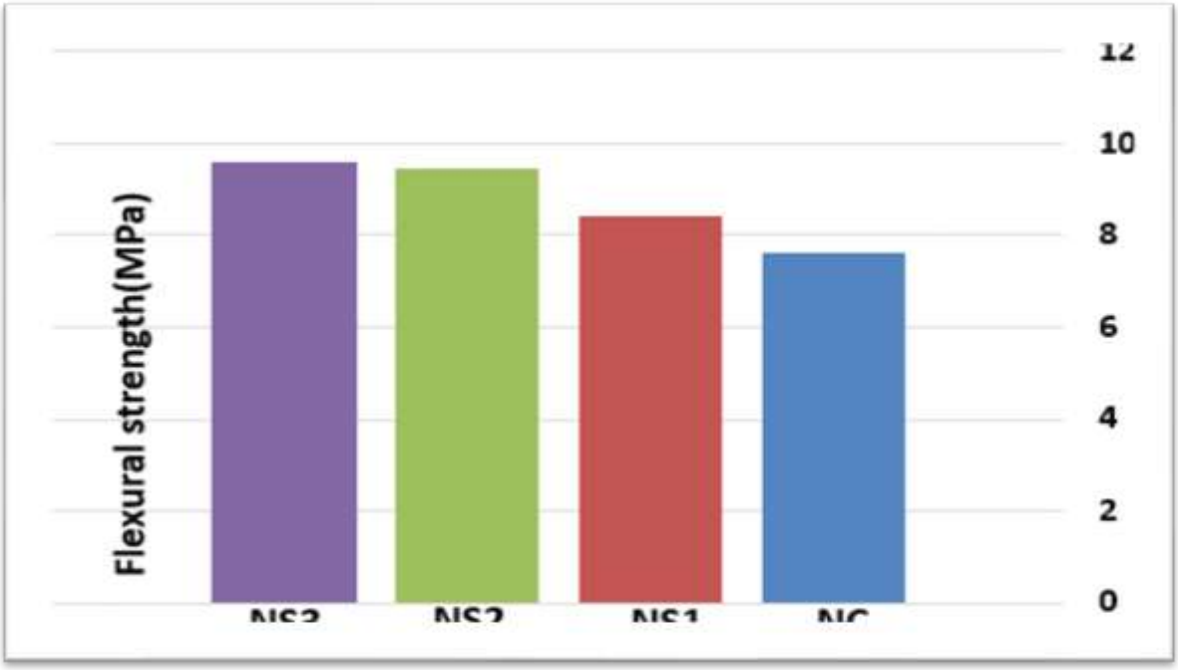

Figure (3): Flexural strength

3.3 Splitting tensile strength

Experiment effects of splitting strength of SF and SiO_2 nanoparticles concretes for every mixture is obtainable for each group with percentages of gain in Fig. 4. When NS and SF content increasing, the splitting strengths of all concretes rise that approving the creation of higher amount of C–S–H gel in the presence of nanoparticles. Splitting tensile strength test is done by a (150×300) mm concrete cylinder with ASTM C496-04[23]. Three cylinder specimens are tested at age of 28 days and the average value of these specimens is determined and recorded.

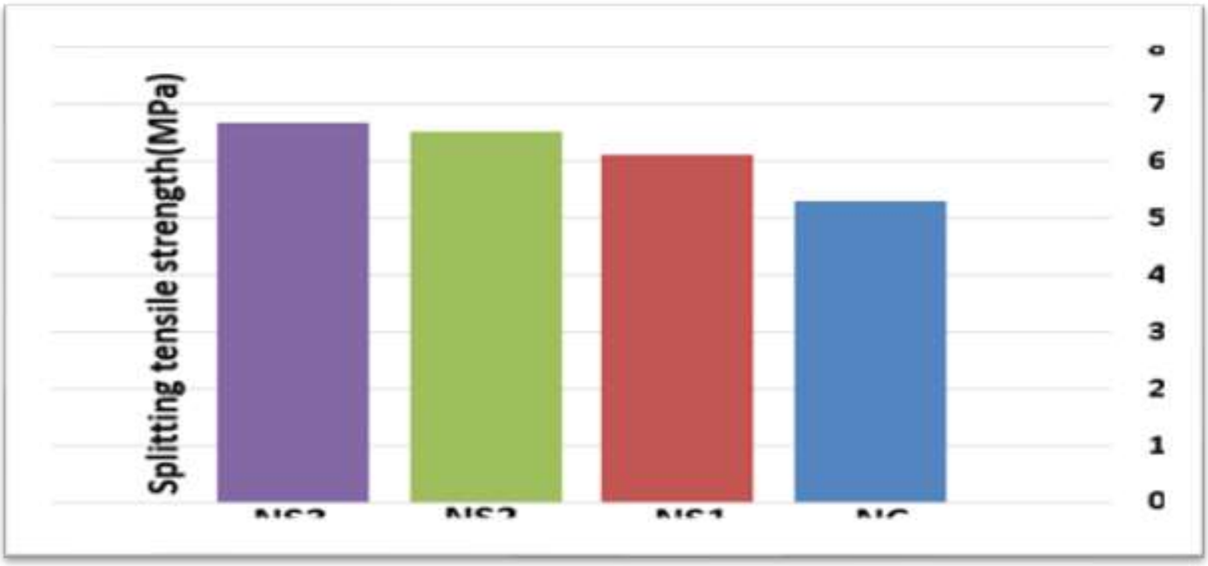

Figure (4): Splitting strength

3.4 Modulus of elasticity

Consequences of modulus of elasticity and improvement percentages offered in fig. 5. It is establish that with addition SF considerably rise modulus of elasticity. It is experiential rise also by adding of NS in concrete, this is in respectable arrangement [19, 20].

After SF satisfied rises to the value of 0.9% optimal modulus of elasticity is reached for the samples with all NS content. Addition NS by 2 wt% increases modulus of elasticity about 5% associated to samples without NS at 0.9% SF.The optimum ratios of NS and SF are recognized in 2 wt% and 0.9% respectively; later that leading to improvement in modulus of elasticity connected to samples without either NS or SF is about 94% according to ASTM C469-02[24]. by technique of secant modulus.

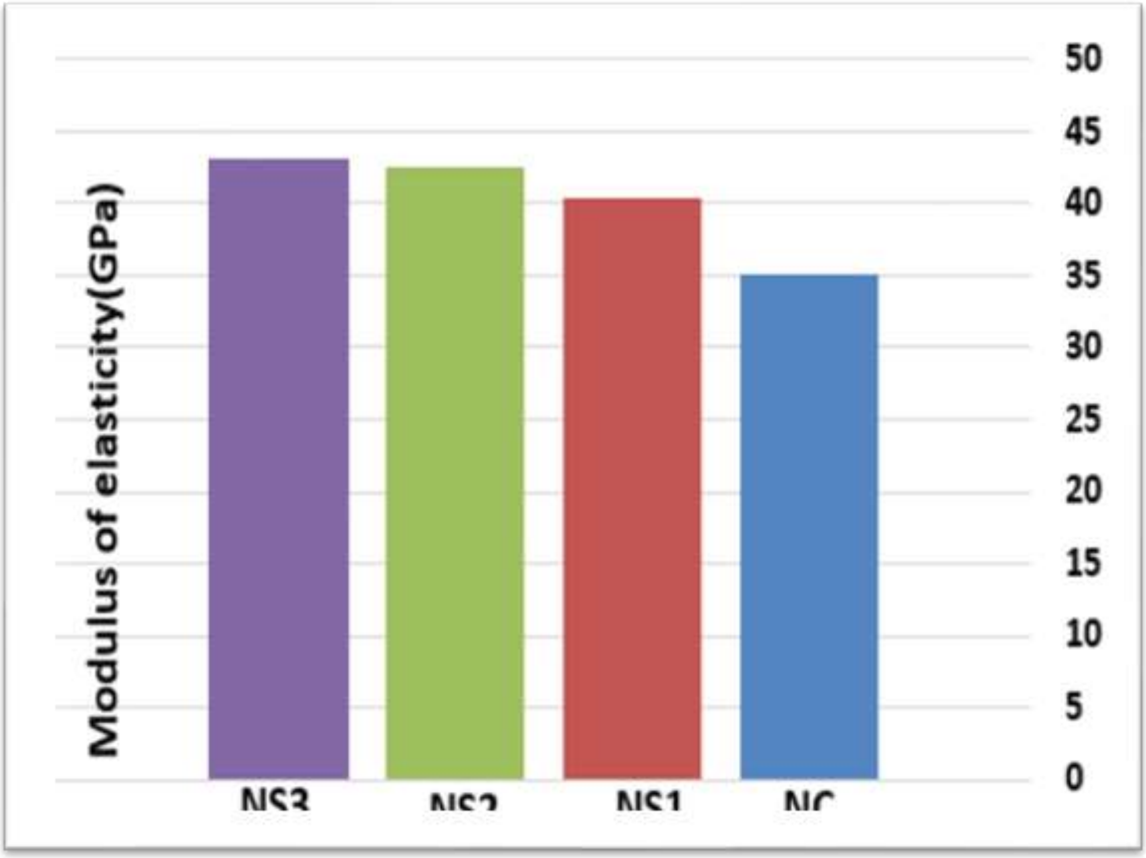

Figure 5 Modulus of elasticity

CONCLUSIONS

The following outcomes can be pointed out:

1. By using nano silica as cement replacement leads to great improvement on mechanical properties of concrete due to its high pozzolanic activity offers huge amount of CSH with decreasing the amount of crystalline CH.

2. Best content of NS is 2wt% increases compressive strength with 1, 1.5, 2 wt% respectively associated to samples without either NS. And can be exhibited that, the compressive strength increase by increasing percentage either NS, using 2wt% of NS 1, 1.5, 2 wt% NS can improve compressive strength about 27.30%, 42.53% and 66.29 % respectively associated to samples without NS

3. The optimum content of NS is 2 wt% increases flexural strength for samples with 1,

1.5, 2 wt% NS can improve flexural strength about 11.05%, 24.43% and 26.60 % respectively associated to samples without NS

4. Best content of NS is 2 wt% increases splitting strength for samples with 1, 1.5, 2 wt% NS can improve splitting strength about 15.68%, 23.06% and 26.46 % respectively associated to samples without NS

5. The best ratios of NS was decided to be 2 wt% leading to improving the modulus of elasticity about 22.99% compared with samples without NS.

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