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EFFECT OF STEEL FIBER CONTENT ON COMPRESSIVE STRENGTH OF HIGH STRENGTH CONCRETE WITH OR WITHOUT NANO-SILICA

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ABSTRACT

During the past few years, high-strength concrete (HSC) has been increased interest amongst civil and structural engineers. On the Other hand, several varieties of fiber-reinforced concretes are now utilized in the building sector for a variety of purposes. This paper discusses the influence of using steel fiber on the compressive strength and splitting strength of high strength concrete with Nano-silica (NS) and/or silica fume (SF). The experimental effort consists of casting and testing 16 distinct mixes. All of the mixes have the same cement content, and some have the same water content and aggregate content, but they differ in factors such as the quantity of NS, SF, and steel fiber. The mixes have been categorized into three main groups. In group one, the impact of adding 3% SF and/or 2% NS was investigated. In group two, the effect of adding 10% SF and the sources of type F admixtures was studied. In group three, two subgroups to study the effect of adding 5% SF, as well as the effect of w/c ratio were considered. As a results, it is established that the average compressive strength of mixes containing fibers to the compressive strength of samples without fibers at 7, 28 and 56 days is 1.04, 1.0 and 1.12, respectively. The average ratio of splitting strength to compressive strength at 28 days is around 7.22%.

KEYWORDS: Compressive strength, High strength concrete, Steel fiber, Silica fume, Nano-silica, Splitting strength

تأثير محتوي الالياف المعدنيه على مقاومه الضغط للخرسانه عاليه المقاومه ب/ بدون نانوسليكا

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الملخص العربى :
خلال السنوات القليله السابقه زاد الاهتمام بإستخدام الخرسانه العاليه المقاومه في مجال هندسه التشييد والبناء . وعلى الجانب الاخر ظهر أســـتخدام الالياف المعدنيه في مجالات متعددة لما لها من مميزات عديدة. هذا البحث يناقش تأثير استخدام الالياف المعدنيه بنسب مختلفه على مقاومه الضغط ومقاومة الشد للخرسانه عاليه المقاومة والمصنعة بإضافه السليكا مع او بدون النانو سليكا. تم صب ١٦ خلطه وتقسيمها الي ٣ مجموعات حسب متغيرات الدراسة السابقة و تم عصر النتائج و وجد ان الحلقات التي تحتوي علي الياف معدنيه عند عمر ٢٨,٧ و ٥٦ يوم كانت مقاومه الضغط لها ١,٠, ١,٠٤, ١,١٢ و مقاومه الشد عند عمر ٢٨ يوم كانت ٧,٢٢٪

1. INTRODUCTION

Since the contemporary introduction of fiber reinforced concrete (FRC) more than sixty years have passed [1-4]. Fiber reinforced concrete exploits the reinforcing action of fibers to prevent the emergence and development of cracks, so substantially boosting the ductility, tensile strength, and impact resistance of concrete [5,6]. Compared to other forms of fiber, steel fiber has a superior reinforcing and toughening impact on concrete, and its low cost and ease of industrial manufacturing make it widely employed in engineering applications. According to pertinent studies [7,8], the use of fibers is intended to lessen the brittleness of the cement matrix. Fibers can affect cracking behavior, regulate the process of brittle fracture, and offer post-cracking strength and hardness [3]. Variations in the fiber reinforcement's composition, aspect ratio, shape, and mechanical qualities serve to distinguish it [9].

Larsen,L., and Thorstensen, R. T., [10] investigated the impact of steel fibers on the compressive and tensile strengths of ultra-high-performance concrete. Fibers have the potential to increase the tensile strength of ultra-high performance concrete UHPC, the researchers determined. The impact is contingent on fiber content, type, and hybridization. The influence of fibers on strength properties is dubious.

Babar A. et-al [11] investigated the impact of varied steel fiber content on the permeability and strength of high strength concrete with micro silica. They tested the characteristics of concrete with and without microsilica inclusion (MS) and steel fiber (SF). The percentages of SF utilized were (0.05, 0.1, 0.25, 0.5, 1, and 2%). There were negative impacts on permeability resistance and compressive strength. In addition to enhancing the strength qualities, the addition of MS to SF increases the interaction between the binder matrix and fibers.

Recently, nanotechnology is an emerging avenue in the construction sector which controls the material in molecular level. Application of nanotechnology in concrete by incorporation of nano materials will tend to produce concrete which exhibits new properties [12-14]. Especially the core property of concrete is holding or binding of aggregate by means of glue which is termed as calcium silicate hydrate (CSH). This CSH gel itself a Nano material which will be observed only on the Nano scale. Nano modification by the inclusion of Nano material enhances the normal concrete properties in terms of strength and durability. There are several Nano materials are widely used in different fields based on its properties and functions. Among them, nano-silica (NS) is a promising material in the concrete sector. Firstly, it influences the pozzolanic reaction which generates additional CSH gel by utilizing calcium hydroxide formed in the cement hydration process. Secondly, it fills the Nano sized pores by its pore filling effect can guide to retard the crack formation in the Nano scale itself [15-17].

Early age specimens of concrete having 15 nm average diameter NS had greater strength than all those containing 80 nm of SiO_2 particles. NS decreases the barrier of concrete to water penetration. This enhancement is mostly attributable to the addition of NS, which has pozzolanic and filler effects on the cement paste [18]. Because nanoparticles result in a denser microstructure, the frost resistance of the material is greatly enhanced [19].

Yasser A. F. and Khaled A. M. [20], examined the effect of steel fiber or NS on the parameters of freshly formed concrete (slump) or compressive strength and splitting tensile. At w/c = 0.45, the NS/cement ratio was 0 and 3%, respectively. Consideration was also given to the impact of cement amounts (350-400 and 450 kg/m^3) on concrete characteristics. The findings confirmed that the slump values of concrete comprising blended cement and sand were greater than those of concrete having OPC. The addition of 3% NS or 1% steel fiber to concrete mix improves the mechanical qualities of concrete prepared with OPC or mixed cement.

Ola A. Q. and Suha A. [21] examined the impact of SF, NS, and steel fiber on the mechanical characteristics of concrete at various ages. They analyzed the effects of NS as a filler with percentages of (0,1,2,3 in addition to 4%) by weight of cement and the combined effect of silica fume (SF) with percentage of (25%) by cement weight and steel fiber with percentage of (1.0% by volume of concrete) on the mechanical properties of concrete. According to their findings, NS increases concrete's strength by filling micro gaps and creating a thick material. Fibers improve the properties of cement-based matrices during the setting and hardening processes. Under the influence of SF, NS, and steel fiber, compressive strength increased by 40.43, 40.56, 41.23, and 37.5%, respectively (3, 7, 14, and 28 days).

Zemei et al., [22] studied the influence of NS and steel fiber on the concrete mechanical characteristics. The NS concentration was found to be within 0% and 2% by cement weight. The test findings demonstrated that the greatest efficient proportion for achieving high performance and excellent bonding capabilities is NS 1%. The compression strength increased by 35%. Additionally, they observed that >1% reduction of the strength was noted, enhancing mass transport qualities by obtaining minimal porosity. Eventually, the chemical characteristics C-S-H improved with age.

Moustafa, [23] investigated the effects of steel fiber and NS on the structural and mechanical characteristics of concrete comprising OPC and 20 mm gravel as coarse aggregate. He stated that the addition of NS to concrete decreased its workability relative to the control mix, with the exception of a 0.5% NS addition. In addition, the slump value fell dramatically as the quantity of nano particles rose from 0.5 to 3%, indicating that the cement and nanoparticles interacted more. The compressive strength has grown dramatically as the fraction of NS has increased. At 3% NS, concrete containing nano-silica acquired its maximum strength.

In this study, an experimental program was designed and carried out to examine the impact of steel fiber on the compressive strength and splitting strength of high strength concrete with NS and/or SF. At 7, 28 and 56 days, the ratio of the average compressive strength of fiber-containing mixes to the compressive strength of fiber-free samples is 1.04, 1.0, and 1.12, respectively. The average ratio of splitting strength to compressive strength at 28 days is around 7.22%.

2.THE EXPERIMENTAL PROGRAM

2.1. The used materials and mixes proportions

Cement CEMI-52.5 N in accordance with the European Standard EN 197-1[24] was utilized in this investigation, and produced by Misr Beni Suef Company, Egypt. The cement CEMI-52.5 N has a specific gravity of 3.15. The fine aggregate was natural siliceous sand and the coarse aggregate was dolomite with nominal maximum size 10 mm as it was the commercial type available that conforms to the requirements of EN196-1 [13]. Type F: Water-reducing, high range admixes, from three companies (sources): HPS from source 1, Edekrite BVF from source 2 , X.MIX from source 3 conform to the requirements of ASTM C494 [14]. These three different sources (companies) were used to compare the effect of admixture source on the compressive and tensile strength of used concrete. End hooked steel fiber with 50 mm length and 1mm diameters was used. SF, NS and tap drinking water were also used in this work.

Table 1 provides the concrete mixture proportions investigated and were calculated using the Empirical method for concrete mix design. The water to cementitious materials ratio (w/c) of the concrete ranged from 0.30 to 0.39. For mix (A) 2% of NS was used. On the other hand, 2% of NS in addition to 3% SF was used for mix (B) while 5% SF was used for mix (D). The SF content was 10% by mass of the cement for mixes (C, and E). The nominal maximum size for coarse aggregate was 10 mm. for all mixes coarse aggregate was dolomite.

Table 1: Proportions of concrete mixes

Mix. ID.	Silica fume kg/m^3	Nano silica kg/m^3	Mix proportions kg/m^3			Water	Admixes Type F kg/m^3	W/C*
			Cement	Coarse Aggregate	Fine Aggregate			
A	---	9.5	475	1102	550	190	19	0.39
B	14.5	9.5	475	1096	548	190	19	0.38
C	47.5	---	475	1131	566	167	19	0.32
D	47.5	---	475	1133	567	167	12.6	0.32
E	23.75	---	475	1147	574	160	19	0.32
F	47.5	---	475	1140	570	156	12.6	0.30

** Water to cementitious materials ratio*

2.2. Details Proportions of the Concrete Studied

The study comprises testing sixteen concrete mixes. The mixes have been categorized into three main groups. The details of these mixes are presented in table 2. The steel fiber content for mixes NS1, NS4, FS1, FS4, FS7 and FS9 was 0.32% (25kg/m^3) while for NS2, NS5, FS2 and FS5 was 0.64% (50 kg/m^3). On the other hand, mixes NS0, NS3, FS0, FS3, FS6 and FS8 have no steel fiber. Mixes NS0 to NS2 were casted using 2% NS and admixtures type F from Source 3, while mixes NS3 to NS6 were casted using 2% NS + 3% SF and admixtures type F from Source2. For mixes FS0 to FS2. The used admixtures was type F from Source 2, while for mixes FS3 to FS5 from Source1. Mix FS6 was casted using 5% SF and admixtures type F from Source 2. For mixes FS7 and FS8 the used admixtures was type F from Source 1.

Table 2: Details proportions of the concrete studied

Group No.	Mix. No.	Mix ID.	Fiber %	Silica Fume kg/m^3	Nano-silica kg/m^3	Admixes Source
One	NS0	A	0	-------	9.5	3
	NS1	A	0.32	-------	9.5	3
	NS2	A	0.64	-------	9.5	3
	NS3	B	0	14.5	9.5	2
	NS4	B	0.32	14.5	9.5	2
	NS5	B	0.64	14.5	9.5	2
Two	FS0	C	0	47.5	-----	2
	FS1	C	0.32	47.5	-----	2
	FS2	C	0.64	47.5	-----	2
	FS3	D	0	47.5	-----	1
	FS4	D	0.32	47.5	-----	1
	FS5	D	0.64	47.5	-----	1
Three	FS6	E	0	23.75	-----	2
	FS7	E	0.32	23.75	-----	2
	FS8	F	0	47.5	-----	1
	FS9	F	0.32	47.5	-----	1

2.3. Preparation and curing of concrete specimens

The 60-liter capacity mixer was utilized. The following are the concrete mixing processes utilized in this investigation. First, the fine and coarse aggregates were combined, then cement and steel fiber were added. After the components were uniformly dispersed, 50% of the mixing water was added, followed by the second half of the mixing water containing SF and/or NS as well as the super plasticizer. This process was repeated until a homogeneous mixture was achieved (due to field experience).

Immediately after mixing, the slump of the fresh concrete was evaluated in accordance with BS 1881-102 [15]. Cube specimens 100 mm side length according to BS 1881-116 [16] were used to determine the compressive strength. Three specimens were cast for each mix to be tested at the specified ages of 7, 28 and 56 days of curing. For selected mixes, additional standard cylinder with diameter 150 mm. and length 300 mm. was casted for indirect tensile test according to ASTM C496 / C496M – 17 [17]. All cubes and cylinders were kept in the casting area for roughly 24 hours before being demolded and cured until testing was necessary. The compressive strength of the concrete was determined after 7, 28 (according to Egyptian code for usual concrete)) and 56 days (cause of presence of SF) for all mixes except for NS0, while indirect tensile test after 28 days. **Fig. 1, 2 and 3** show NS, steel fiber, and compressive strength test, respectively.

Fig.1: Nano-silica

Fig. 2: Steel fiber

Fig. 3: Compressive strength test

3. Experimental Results and Discussion

The parameters of the mixtures in their fresh and hardened forms are listed in Table 3. The average findings of three compression tests conducted on cubes cast after 7, 28, and 56 days are presented in Table 3 as the average of the three tested cubes.

Table 3: The characteristics of fresh and hardened mixtures

Group No.	Mix No.	Slump (mm)	28 days Splitting strength (MPa)	Compressive strength (MPa)		
				7days	28 days	56 days
Group One	NS0	260	-----	43.7	48.3	-----
	NS1	150	2.791	40.33	51.67	51.7
	NS2	100	4.4	46	55.83	56
	NS3	90	-----	55.3	58	58.3
	NS4	130	3.698	56.33	64.33	65.3
	NS5	70	4.326	55.33	67.5	75.7
Group Two	FS0	70	-----	49.3	62.5	67.33
	FS1	25	5.58	44.2	60	86.33
	FS2	45	6.28	51.3	68.3	85
	FS3	200	-----	51.5	65.2	89.5
	FS4	180	4.46	55.8	61.3	85.67
	FS5	15	4.81	66.7	76.7	88.17
Group Three	FS6	20	-----	59	67. 7	68.66
	FS7	12	5.1	60.3	71	71.67
	FS8	15	-----	56	77.7	85.0
	FS9	100	4.61	59.3	68.7	89.17

According to Table 3, the compressive strength values for group one from NS0 to NS5 were at 7 days (43.7-55.33 MPa), at 28 days (48.3-55.83 MPa), and at 56 days (51.7-75.7 MPa). Group two (FS0 to FS5) were at 7 days (44.2-66.7 MPa), from at 28 days (60-76.7 MPa), and at 56 days (67.33-88.17 MPa). While for group three (FS6 to FS9), they were at 7 days (59-60.3 Mpa), at 28 days (67.7-77.7 MPa), and at 56 days (68.66-89.17 MPa).

The splitting strength at 28 days ranged from 2.79 to 4.4 MPa for group one, group two ranged from 4.46 to 6.28 MPa and from 4.6 to 5.1 for group three. In the following subsections, the results of each property and the influence of different factors will be discussed.

3.1. Fresh Concrete Properties

Table 3 shows that the slump of mixes group one (NS0 to NS5) ranged from 70 to 260 mm, for group two (FS0 to FS 5) the slump ranged from 15 to 200 mm, while slump was ranged from 12 to 100 mm for mixes FS6 to FS (group three).

3.2. Hardened Concrete Properties

The effect of fiber ratio, admixture source, SF ratio, NS ratio and the age of specimens on the compressive strength are studied through the results of the three groups of mixes which illustrated in the experimental program

3.2.1. Group one mixes SN0 to SN5

Fig. 4 and table 2 show the compressive strength for mixes NS0 to NS5 which represent the influence of presence of SF in addition of NS in mixes NS3 to NS5 comparing with using NS only in NS0 to Ns2 mixtures containing different proportion of fibers at different periods of concrete ages (7,28 and 56 days). The figure demonstrated that for all mixtures, a rise in the age of concrete was related with an increase in its compressive strength. Comparing the results of mixes NS0 to NS2 which have not SF with mixes NS3 to NS5 which contain SF in addition of NS illustrate enhancement in compression strength in case of presence of SF in addition of NS. Also, an improvement in compressive strength has been observed for most mixes whenever the percentage of fiber is increased. The compressive strength of mixtures containing fibers ranged from 0.92 to 1.16 of the compressive strength of mixes without fibers. The compressive strength of mix NS5 at 28 days and 56 days was 67. 5 and 75.7 MPa respectively, which was considered the highest value for mixes NS0 to NS5, this finding may be returned to using SF in addition to NS and 0.64% of steel fiber. Conversely, the splitting strength at 28 days of these mixes ranged from 2.79 to 4.396 MPa.

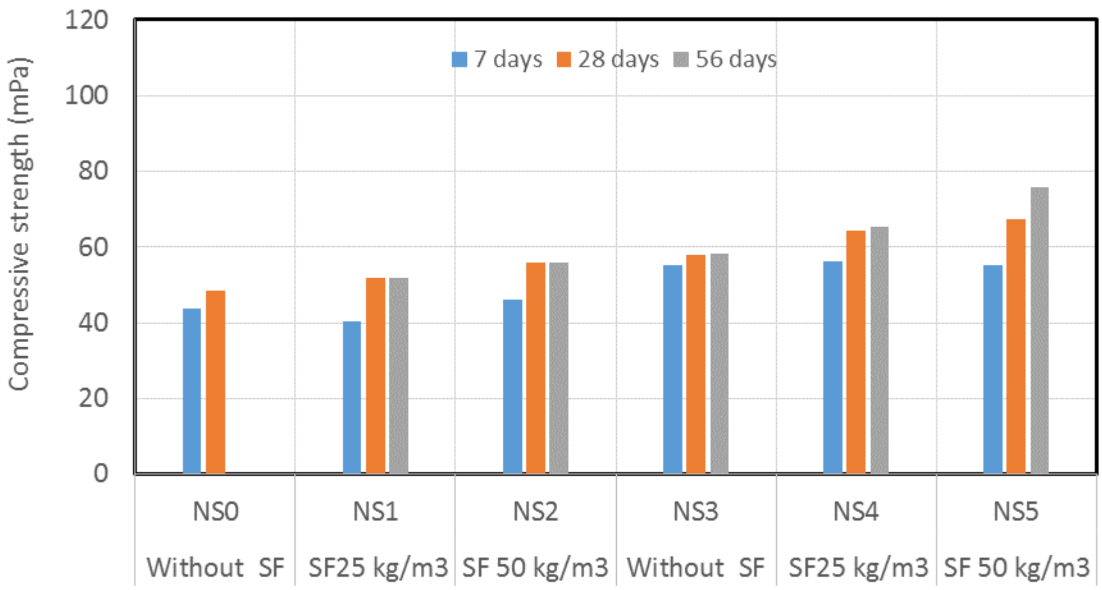

Fig. 4: The compressive strength for mixes NS0 to NS5.

3.2.2. Group two mixes FS0 to FS5

The compressive strength for mixes FS0 to FS5 is shown in **Fig. 5** which explain the impact of admixture source (two sources were utilized, the first source for mixes No. FS3, FS4 and FS5, and the second source for mixes No. FS0, FS1 and FS2) with three different percentage of fiber for each source at diverse ages (7, 28, and 56 days). The effect of the age on the compressive strength are compatible with the investigation of the results in group one which demonstrate a significant increase in compressive strength with increasing age and proportion of fibers. The compressive strength of mix FS3 at 56 days was 89.5 MPa which was considered the highest value for mixes FS0 to FS5, which demonstrate the increase in compressive strength in case of using admixture from the first source than that from the second source. On the other hand, the splitting strength at 28 days of these mixes ranged from 4.46 to 6.28 MPa.

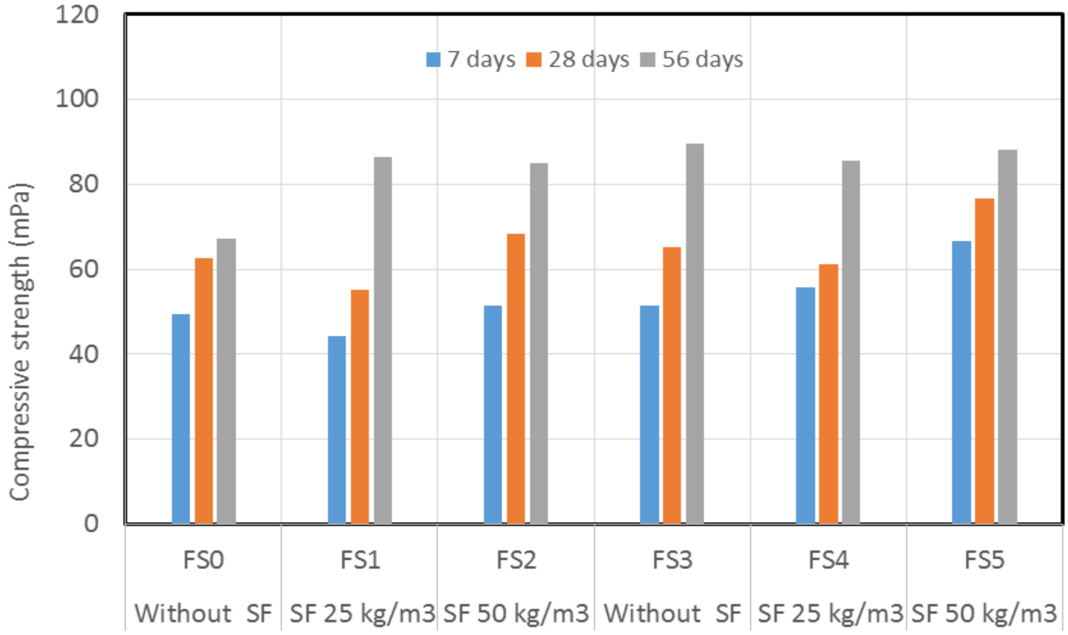

Fig. 5: The compressive strength for mixes FS0 to FS5

3.2.3. Group three mixes FS6 to FS9

The compressive strength for mixes FS6 to FS9 is shown in **Fig. 6** which represent the effect of SF percentage (mixes FS6 and FS7 contains SF less than mixes FS8 and FS9) at 7-day, 28-day, and 56-day intervals of concrete ages. An increase in compressive strength is related with a rise in SF content especially in old ages which is related to the effect of pozzolanic reaction. The compressive strength of mix FS٩ at 56 days was 89.17 MPa which was considered the highest value for mixes FS6 to FS9, this finding may be returned to using higher percentage of SF in addition to adding the steel fiber. Contrarily, the splitting strength at 28 days of mixes FS7 and FS9 was 5.1 and 4.61 MPa, respectively.

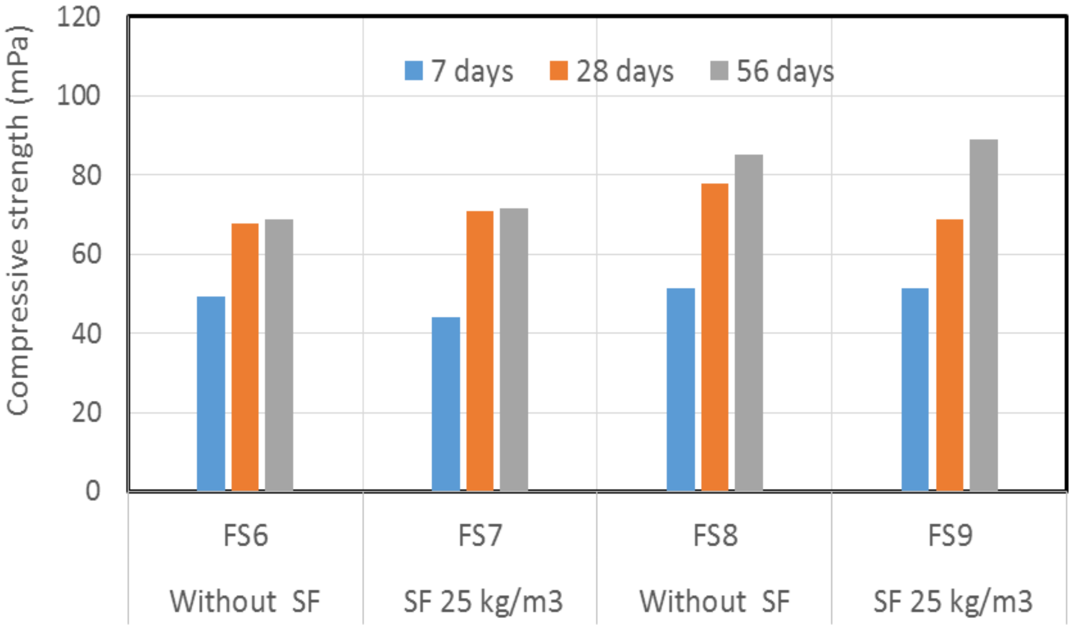

Fig. 6: the compressive strength for mixes FS6 to FS9.

3.2.4. Effect of Steel Fiber Content on Compressive Strength

compares the average compressive strength of fiber-containing mixtures to that of fiber-free samples ie, the relative compressive strength for all mixes at 7, 28 and 56 days. It is evident that the compressive strength of mixes including 25 kg/m^3 steel fibers varied between 0.88 and 1.28 times that of mixtures without fibers. However, the compressive strength of mixtures with 50 kg/m^3 steel fibers ranged between 0.99 and 1.30 times that of mixtures without fibers. At 7, 28 and 56 days, the ratio of the average compressive strength of mixtures containing fibers to the compressive strength of samples without fibers is 1.04, 1.0, and 1.12, respectively. This result may be attributed to the three distinct factors that contribute to the compressive strength property resulting from the incorporation of fibers. The first factor is the confining impact of fibers, which enhances the concrete's stiffness and is recognized to have a favorable influence on its compressive strength. The second phenomena is the entrainment of extra ITZs in concrete, which has a negative impact on compressive strength. A large number of ITZs introduces porosity and permeable pathways into concrete, and ITZs function as a weak link in the fibrous composite. The third phenomena relates to the resistance of cracking to the development of micro and macrocracks. Consequently, it is known to increase the compressive stiffness of concrete [11].

Table 4: The relative compressive strength for all mixes at 7, 28 and 56 days.

Mix No.		NS1	NS2	NS4	NS5	FS1	FS2	FS4	FS5	FS7	FS9
Fiber content kg/m^3		25	50	25	50	25	50	25	50	25	25
CSR*	7 days	0.92	1.05	1.02	1.00	0.90	1.04	1.08	1.30	1.02	1.06
	28 days	1.07	1.16	1.11	1.16	0.96	1.09	0.94	1.18	1.05	0.88
	56 days	---	---	1.12	1.30	1.28	1.26	0.96	0.99	1.04	1.05

*Compressive strength of samples containing fibers to that of samples without fibers

3.2.5. Effect of Admixtures Source on Compressive Strength

Table 5 and **Fig. 7** show the effect of admixtures source on compressive strength by comparing each two mixes had the same components with the same percentage, only changes in the source of material in each two mixes. It is clear that the compressive strength of mixes casted using admixtures from source (1) is more than that of the compressive strength of mixes casted using admixtures from source (2), it shall return to the product quality and contents from each source

Table 5: The effect of admixtures source on compressive strength.

Mix No.		FS3	FS0	FS4	FS1	FS5	FS2
Fiber content %		0	0	0.32	0.32	0.64	0.64
Admixtures source		1	2	1	2	1	2
Compressive strength (MPa)	7 days	51.5	49.3	55.8	44.2	66.7	51.3
	28 days	65.2	62.5	61.3	60	76.7	68.3
	56 days	89.5	67.33	85.67	86.33	88.17	85

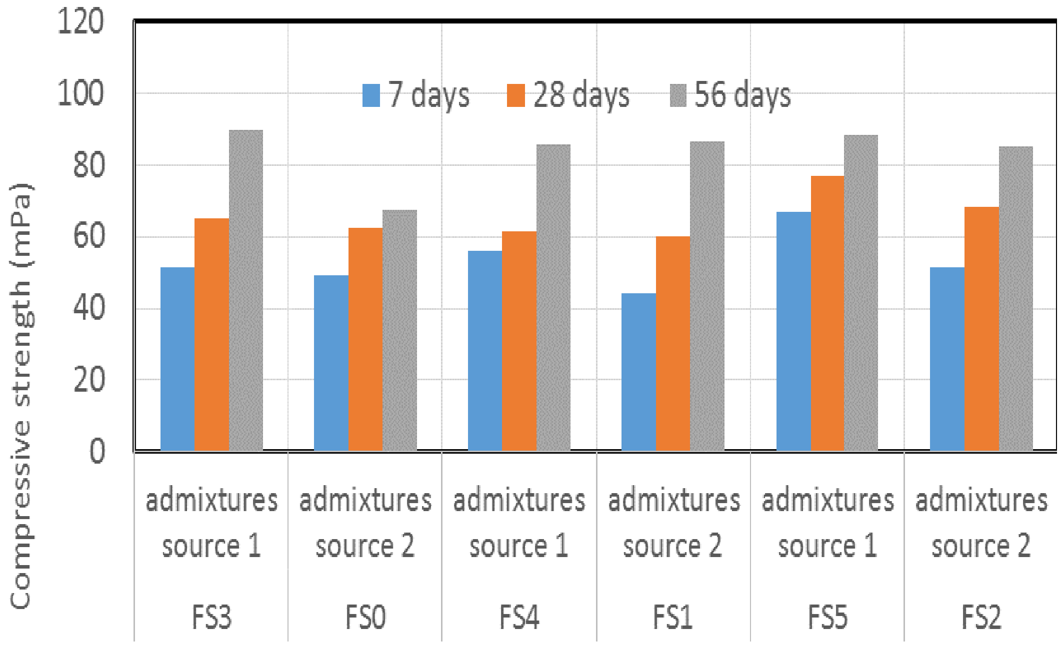

Fig. 7: The effect of admixtures source on compressive strength

3.2.6. Effect of W/C Ratio on Compressive Strength

Table 6 and **Fig. 8** show the effect of W/C ratio on compressive strength. With decreasing w/c ratio from 0.30 to 0.32, the compressive strength increasing in all different ages with average by about 7.7 %. This conclusion conforms to the basic premises of the strength versus water-cement ratio, namely: (a) the strength of the cement paste present in structural concrete determines its strength; (b) The porosity of cement paste has a significant impact on its strength; and (c) Porosity (capillaries) is a result of the ratio of water to cement.

Table 6: The effect of W/C ratio on compressive strength.

Mix No.		FS8	FS3	FS9	FS4
Fiber content kg/m^3		0	0	25	25
W/C ratio		0.30	0.32	0.30	0.32
Compressive strength (MPa)	7 days	56	51.5	59.3	55.8
	28 days	77.7	65.2	68.7	61.3
	56 days	85.0	89.5	89.17	85.67

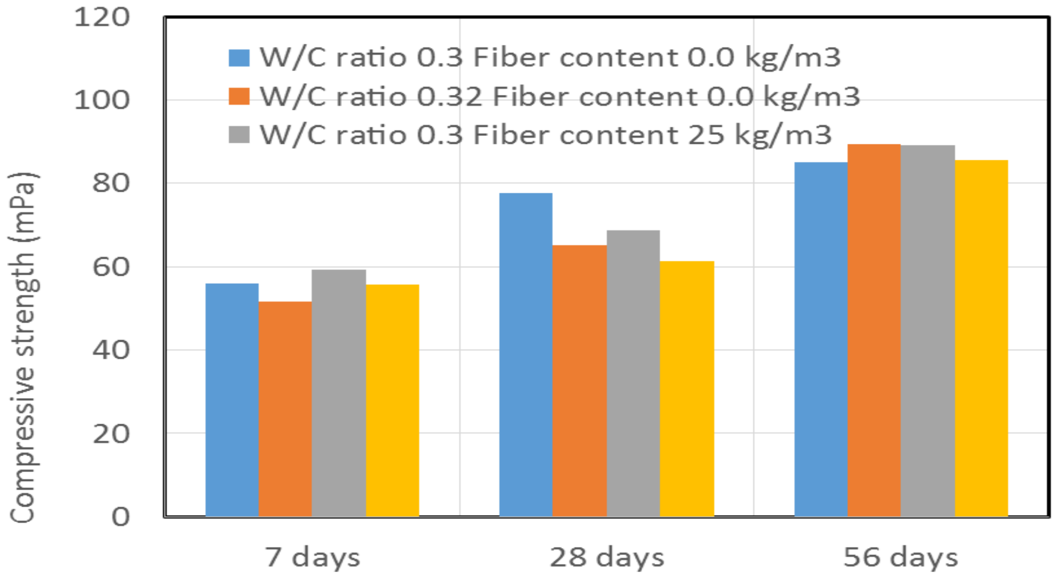

Fig. 8: The effect of W/C ratio on compressive strength.

3.2.7. The Relation between Compressive And Splitting Strength

Concrete's real tensile strength is approximated by its splitting tensile strength. Due to the difficulty of determining the genuine tensile strength using the direct tension test, the true tensile strength is seldom measured. Cementitious materials' tensile strength may be measured more simply using the splitting tensile strength [11]. **Table 7** and **Fig. 9** show the ratio between splitting strength to compressive strength (SCR) at 28 days for mixes containing steel fiber. It is clear that the splitting strength at 28 days ranged from 5.14 % to 10.15 % of the compressive strength at 28 days and the average was 7.22 %. This demonstrates that fibers contribute more to the tensile stiffness of concrete than the compressive stiffness.

Table 7: The ratio between splitting strength to Compressive strength (SCR) at 28 days

Mix No.	NS1	NS2	NS4	NS5	FS1	FS2	FS4	FS5	FS7	FS9
SCR % at 28	5.4	7.9	5.7	6.4	10.1	9.2	7.3	6.3	7.2	6.7

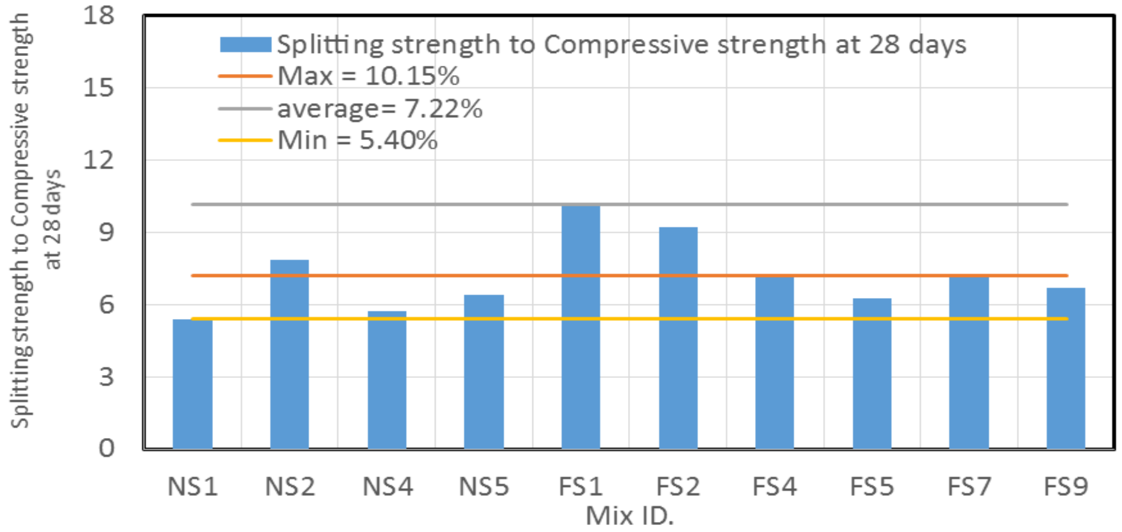

Fig. 9: The ratio between splitting strength to Compressive strength (SCR) at 28 days.

SUMMARY AND CONCLUSIONS

In this research work an experimental program was conducted aiming to study the effect of steel fiber on the compressive strength and splitting strength of high strength concrete with or without NS and/or SF. 16 high-strength concrete mixtures including NS and/or SF were developed. The influence of the researched factors on the physical and mechanical characteristics of fresh and cured concrete was investigated through laboratory testing. On the basis of the given experimental data, the following inferences may be made:

1) Fiber had conflicting effects on The compressive strength of mixtures containing 25 kg/m^3 steel fibers varied between 0.88 and 1.28 times that of mixtures without fibers.

2) Fiber have mixed effect on The compressive strength of mixes containing 50 kg / m^3 steel fibers ranged from 0.92 to 1.30 of the compressive strength of mixes without fibers. However, improvements were frequently noticed in the majority of mixes.

3) At 7, 28 and 56 days, the average compressive strength of fiber-containing mixtures relative to the compressive strength of fiber-free samples is 1.04, 1.0, and 1.12, respectively.

4) Decreasing w/c ratio from 0.32 to 0.3, the compressive strength increasing in the average by about 7.7 %.

5) Enhancement in the tensile strength for the mixes which contain fiber with or without NS and/or SF. The splitting strength at 28 days ranged from 5.14 % to 10.15 % of the compressive strength at 28 days.

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