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Original Research

Evaluation the influence of steel-fiber on the concrete characteristics

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ABSTRACT

The impact of steel fibers on the engineering characteristics of concretes were explored experimentally in this work. Steel fibers of 0.5, 0.7, and 0.9 percent by volume fraction were applied to concretes mixture with water/cements (W/C) proportions of 0.43 to accomplish this. There has been a total of 24 cubic specimens produced for compressive strengths testing, 24 cylindrical specimens for splitting tension strengths testing, and 12 cubic specimens for toughened unit weight testing. The experimental findings reveal that applying 0.5 percent to 0.9 percent of fibers made of steel to concrete boosts both compressive and tension strengths concurrently when compared to ordinary concretes; however, there is no discernible gain in hardened unit weight with increased fiber amounts.

Keywords: Steel-fibers, Engineering Characteristics, Fresh and Hard Concrete

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1. Introduction

Concrete was the most prevalent and extensively utilized material, despite the fact that its compressive strength is substantially higher than its tensile strength. Steel fiber, PVA, charcoal, basalt, glass, and synthetic materials have been used to compensate for concrete's low tensile strengths [1]–[3]. Different sorts of study were conducted on improving mechanical characteristics in concrete utilizing various fibers [4]–[13]. Fiber may significantly improve the mechanical characteristics of concrete [5], [14]–[17]. Steel fiber offers several benefits over other fibers, including tensile strength, elasticity modulus, and high stiffness. Steel fiber reinforcing concretes (SFRC) is a commonly utilized structural material with outstanding tensile and flexural characteristics [18]–[21]. The reinforcement mechanisms of steel fiber on concretes has been extensively explored so as to increase the reinforced impact of steel fiber [22]–[24].

It is well accepted that the mechanical characteristics of steel fiber reinforcement concretes (SFRC) improve as the steel fiber amount rises. On the other hand, steel fiber does not seem to have a major impact on compressive strength, according to certain research [15], [25]. Once the volume percentage of steel fiber has been more than 1.0 percent, the axial compressive strengths virtually stays the same [26]. According to other research, raising the fiber (steel type) volume fraction from 0.5 percent to 1.5 percent for fairly high strength concretes enhance compressive strength approximately 25 percent [27]. Steel fiber inserted to concrete has been demonstrated in certain studies to enhance the compressive strength of concretes by 4–19 percent [28], [29]. Steel fiber in concretes improve the flexural strength and split tensile of concretes substantially [30]. Steel fiber reinforcement concretes (SFRC) has a greater split tensile strength than the control mix by roughly 11–54 percent. Furthermore, the flexural strengths of (SFRC) are 3–81 percent greater than the reference combination. Furthermore, the flexural strength increase proportion was larger than the compressive strengths and split tensile increase proportion [31]. The concrete compressive and split tensile strengths has been modified by the inclusion of hooks end steel fibers with varied aspect ratios and crimped round steel fibers, and it has been discovered that both fibers at various proportions for the same mixture have impacted both characteristics [32]. For varied amounts of steel fibers, flexural and split cylinder tensile strengths improved by up to 30 percent as comparison with ordinary concretes [33], [34]. The influence of fiber length and installation technique on tension-softening curves, flexural behavior, and fiber distribution features of ultrahigh-performance concretes was investigated by Yoo et al. [35]. The impact of fibers (glass and steel type) on the engineering qualities of concretes was explored empirically by Akbari and Abed [36]. Glass and steel fibres have been added at 0.3, 0.6, and 0.9 percent by volume fraction in concretes compositions with water/cements (W/C) proportions of 0.35 and 0.45 in this research. Experiments reveal that inserted 0.3 to 0.9 percent steel fibers to concretes boosts flexural, tensile, and compressive strengths all at the same time when compared to normal concretes.

2. Materials and methods

2.1. Materials

The applied cement in the current investigation is ordinary Portland cements (kind I). Ordinary Portland cement was produced in Iraq's north (United Cement Company, UCC) [37], and had been commercially marketed as (Crista). Table 1 and Table 2 provide the physical parameters and chemical analysis of the cement applied in this research. They are in compliance with Iraqi standard (IQS) No. 5/1984 [38]. These tests are carried out at Al-mustaqbal University College's Construction Materials Lab.

Table 1. Oxide analysis and Main Compounds of Cement Applied in the investigational work

Compositions	**Amount percentages by weight**	**Iraqi specification Limits No.5/1984**
CaO	62.23	—
SiO2	19.5	—
AL2O3	4.56	—
Fe2O3	3.56	—
SO3	2.59	2.5 ≥percent If C3A < 5 percent ≤ 2.8 percent If C3A > 5 percent
MgO	2.95	≤ 5 percent
Free CaO	1.12	—
L.O.I	4	≤ 4 percent
I.R	1.23	≤1.5 percent
L.S.F	0.95	0.66-1.02
Major compounds (Bogue's equations)	**Percentages by cement weights**	
C3S	57.47	
C2S	12.55	
C3A	6.06	
C4AF	10.83	

Table 2. Physical Characteristics of the Cement Applied in in the experimental tests

Physical characteristics	**Test Finding**	**Limit of Iraqi requirement No. 5/1984**
Fineness (Blaine Technique , m^2/Kg)	310	≥ 230.0 m^2/Kg
Setting time (Vicat's Technique) Initially Setting time, minute Finally Setting time, minute	 120 235	 ≥ 45 min ≤ 600 min

Physical characteristics	Test Finding	Limit of Iraqi requirement No. 5/1984
Mortar Compressive strengths MPa 3- days 7- days	19 28	≥ 15 MPa ≥ 23 MPa

In addition, Superplasticizer (SP)RHEOBUILD® 600 seems to be a ready-to-use, high-water-reduction ranges additive that produces great-slump concrete with good workability. The product seems to be a chloride-free high-water-reduction ranges additive in liquid form for superplasticizer concrete that retains workability. RHEOBUILD® 600 is usually applied at a rate of (0.5-1.2) liters per 100kg of cement. Based on the exact working circumstances, other doses may be employed. To boost workability without modifying the water/cement proportion, superplasticizer (SP) was utilized. It may also be utilized to raise the final strength of concretes by lowering the moisture amount whereas keeping the workability.
Fine Aggregate (Sand), In this investigation, river sand from the (Al-Akaidur) area has been utilized in concrete mixtures. Prior usage, the sand has been washed, rinsed with water, and dried. The fine aggregate's grading and the restrictions of Iraqi requirement No.45/1984 [39] are demonstrated in Figure 1. The fine aggregate's physical parameters were illustrated in Table (3). All the tests of fine aggregates are performed by the Environmental and the Constructional Materials Laboratory of Al Mustaqbal University College.

Table 3. Chemical and Physical Features of sands

Physical Characteristics	Test Finding	Iraqi requirement Limits No.45/1984
Specific gravity	2.60	-
Sulfate amount	0.08 %	≤ 0.50 %
Absorption	0.75 %	-
Clay amount	0.83%	≤1 %

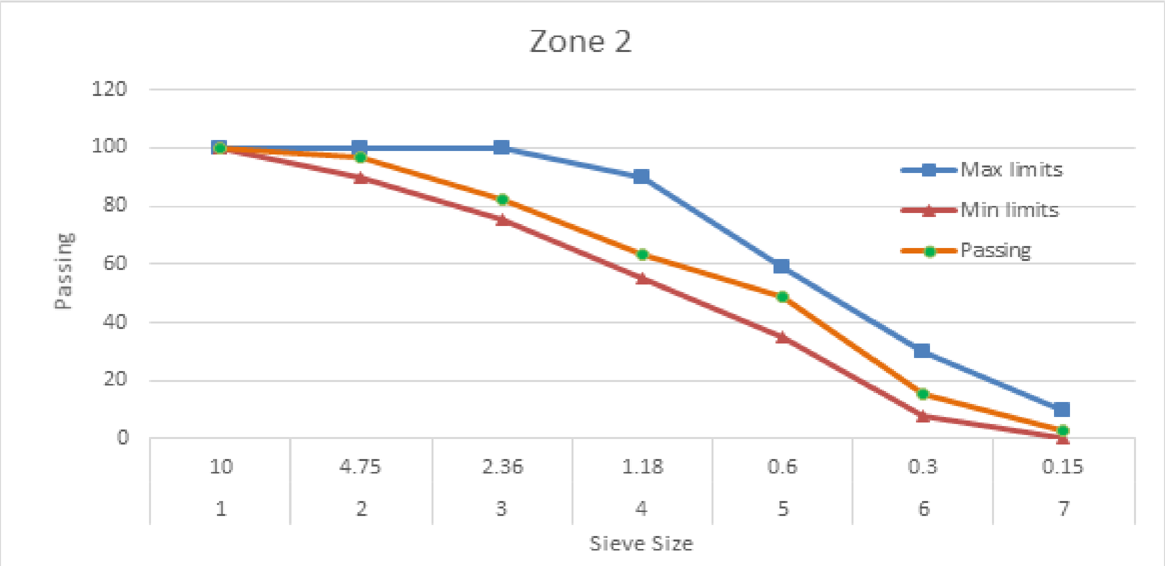

Figure 1. The curve of fine aggregate grading with grading limitations of zone 2

2.1.1. Coarse aggregate (gravel)

The aggregate was rounding coarse aggregates with a size of 0.14 m as a max aggregate size. Water has been applied to wash and rinse the gravel multiple times till the outgoing washing water had been extremely clean, and then it was dried before use. The coarse aggregates grading is given in Table 4 and Figure 2. According to the findings, the coarse aggregates classification met the standards of Iraqi requirement No. 45/1984 [39]. The Construction Materials Lab of Al-mustaqbal University College conducts grading exams. Observe Table 4 for more details about specific gravity, sulfate concentration, clay amount, and absorption.

Table 4. The Sieve analysis for gravel

Sieves size (mm)	% Passing weights	Iraqi requirement Limits No. 45/1984
14	100	100
10	92	85-100
4.75	15	0-25
2.36	3	0-5

Table 5. chemical and Physical Features of gravel

Physical Characteristics	Test Finding	Iraqi requirement Limits No.45/1984
Specific gravity	2.65	-
Sulfates amount	0.03 percent	≤ 0.1 percent
Absorption	0.5 percent	-
Clay amount	0.2 percent	≤2 percent

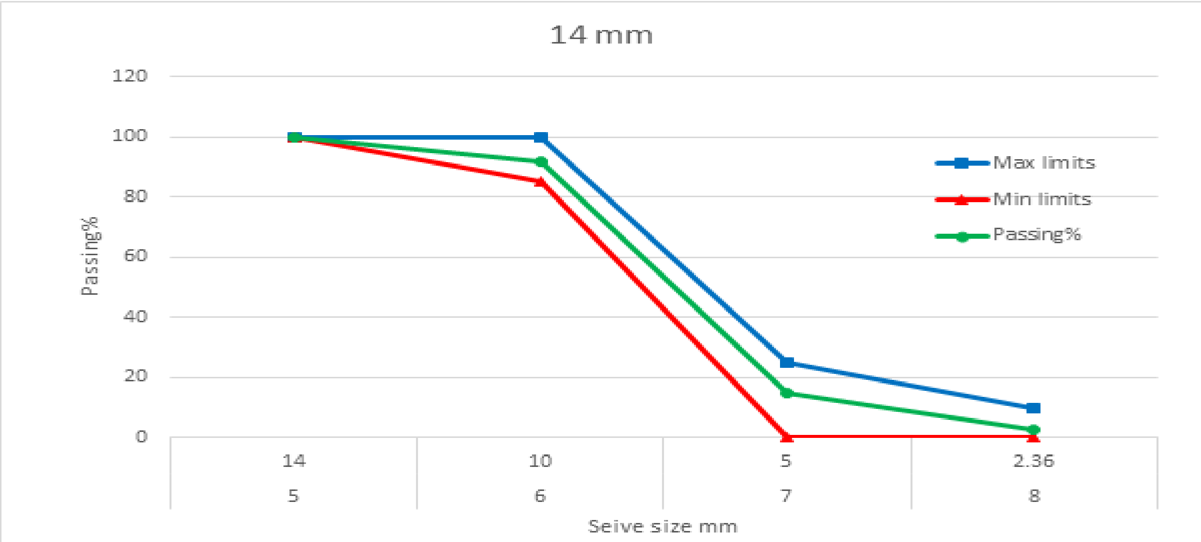

Figure 2. Coarse aggregates analysis

Water, In the current experimental work, Potable water has been utilized for both preparing and curing the specimens of all selected tests

Steel Fibers, Hooked-end hard-drawn wire fibers, conforming to the provisions ASTM A820 have been utilized for the SFRC in the current empirical work. The characteristics of the utilized steel fibers-bare details in Table (6).

Table 6. characteristics of fibers (steel type with hooking ended)

Length cm	Diameter cm	Aspect proportion $\frac{L_f}{D_f}$	Tensile Strengths MPa	Elasticity Modulus (GPa)	Density Kg/m3
3.5	0.05	70	1300	200	7500

2.2. Concrete mix proportion and working procedure

Four distinct concrete mixtures have been made in all. The concrete mixture has been depending on the American approach (ACI 211-1.91) [40], and the mix specifics were seen in Table (7). The mixtures have been made with a consistent water/cement proportion and a high amount of superplasticizer.

Table 7. Mixing proportion details

Concrete Mix Grade 25N/mm2				
Mix No.	**Types on Concrete**	**W/C proportion**	**SP (%by weight of cement)**	**Sf (%) by volume**
1	NC	0.43	1.2	0
2	A	0.43	1.2	0.5
3	B	0.43	1.2	0.7
4	C	0.43	1.2	0.9
Materials	**Cement (Kg/m^3)**	**Sand (Kg/m^3)**	**Gravel (Kg/m^3)**	
Amounts	410	640	1250	

All aggregates have been introduced to the mixer and combined for a few revolutions to guarantee water absorption by the aggregate, after that the cement has been combined in a dry condition for a few mins. The aggregates were combined for three minutes with premixed super plasticizer and water, then rested for three minutes before being combined again for two minutes. The mixer has been turned off, and the concrete mixture is poured into various molds based on the size of the samples. Fibers have been applied to the concretes after the concrete mixture was prepared and stirred for 5 minutes to confirm that the fibers have been evenly distributed throughout the concrete. Slump flow and compaction factor tests are performed on all new concrete mixtures. In stiff plastic molds, concrete cube samples of 15x15x15 cm have been produced for the standard compressive strength and hardened unit weight tests. For the splitting tensile strengths, cylindrical samples of 15x30 cm were constructed. For each kind of test and every combination, three samples were cast. During 7 and 28 of curing days, splitting tensile and compressive strengths samples have been evaluated, whereas hardened unit weight samples have been assessed after 28 days. The three samples' mean strengths had been calculated and given in the findings. Figure 3 depicts the sample preparation and testing method.

(a) Sieve Analysis & Mixing

(b) Workability Test

(c) Preparation of specimens & Casting

(d) hardened tests

Figure 3. Preparation of the materials, mixing, fresh tests and hardened tests

3. Results and discussion

3.1. Workability test

One of the goals of this research is to test concrete in its raw condition. For this study's mixtures, the slump flow and compaction factor are employed.

3.1.1. Slump flow test (mm)

Table (8) and Figure 4 demonstrate the findings for slump flow of concretes with steel fiber. Because of the lower flowability of fresh concretes, the incorporation of fibers in concretes caused by a steady decrease in slump flow diameter. Once steel fibers were added from 0.5 percent to 0.9 percent, slump flow spread fell from 20 cm for the controlling mixture with absence fibers to (6 and 2) cm. This behavior might be explained by the increased friction between aggregates and the larger fiber amount, which changes the viscosity and flowability of steel fiber concrete mixtures [41]–[43]. Yap et al., [44] detected that inserting steel fibers lowered the diameter of slump flows for evaluated steel fibers concrete mixtures, owing to the increased surface area of the fibers that necessitates additional mortar within the paste matrix.

Table 8. Slump Results

Mix No.	Types on Concrete	W/C ratio	Sf %	Slump (mm)
1	NC	0.43	zero	200
2	A	0.43	0.5	60
3	B	0.43	0.7	35
4	C	0.43	0.9	20

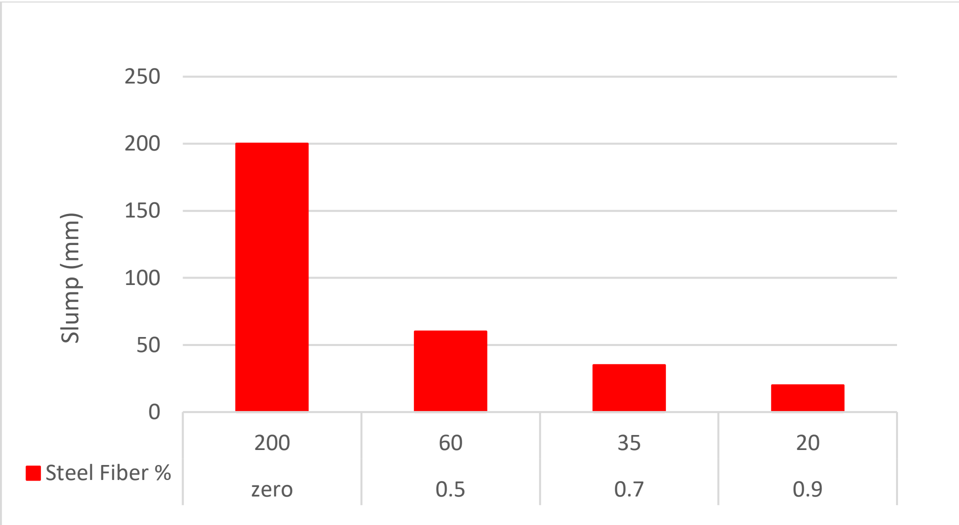

Figure 4. The impact of adding steel fibres on the concrete's slump

3.1.2. Compaction factor testing

Table 9 demonstrates the findings for the compaction factor of steel fibers concretes. The data is being collected and analyzed to see whether there is a link between the proportion of steel fibers and the compaction factor.

Table 9. The Compaction factor Result

Mix No.	Types on Concrete	W/C ratio	Sf %	Compaction test
1	NC	0.43	zero	0.9
2	A	0.43	0.5	0.905
3	B	0.43	0.7	0.926
4	C	0.43	0.9	0.94

The results show that the compaction factor increased by using the steel fiber.

3.2. Physical characteristics of hardened concretes

3.2.1. Compressive strengths

Tables (10 and 11), and Figure 5 indicate the mean compressive strengths findings of the three samples at 7 and 28 days for all mixtures with varying fiber proportions. The applying of fibers to concrete has boosted the compressive strengths, as can be observed. After 7 days, a slight rise in compressive strength of around (10.8,11.1 and 13.7) percent has been found, whereas enhancements in compressive strength equal to approximately (14, 25 and 32) percent were observed at 28 days with an increase in fiber amount of (0.5,0.7 and 0.9) percent. The restricting impact supplied by the fibers to the concretes might well be responsible for the increase in compressive strengths. Meanwhile the propagation of fractures was stopped, the ultimate concrete's compressive strengths increased, depending on the binding strengths of the steel fibers and the matrices.

Table 10. Compressive strengths of steel fiber reinforcement concretes at 7 days

Mix No.	**Types on Concrete**	**Sf %**	**7 days**			**Mean compressive strength MPa**
			1	**2**	**3**	
1	NC	zero	21.56	19.67	23.33	21.52
2	A	0.5	23.33	24.73	23.48	23.85
3	B	0.7	23.38	23.82	24.56	23.92
4	C	0.9	22.59	25.05	25.80	24.48

Table 11. Compressive strengths of steel fiber reinforcement concretes at 28 days

Mix No.	**Types on Concrete**	**Sf %**	**28 days**			**Mean compressive strength MPa**
			1	**2**	**3**	
1	NC	zero	31.19	29.51	27.32	29.34
2	A	0.5	33.22	35.90	31.77	33.63
3	B	0.7	34.89	39.26	35.75	36.63
4	C	0.9	38.16	39.57	38.27	38.67

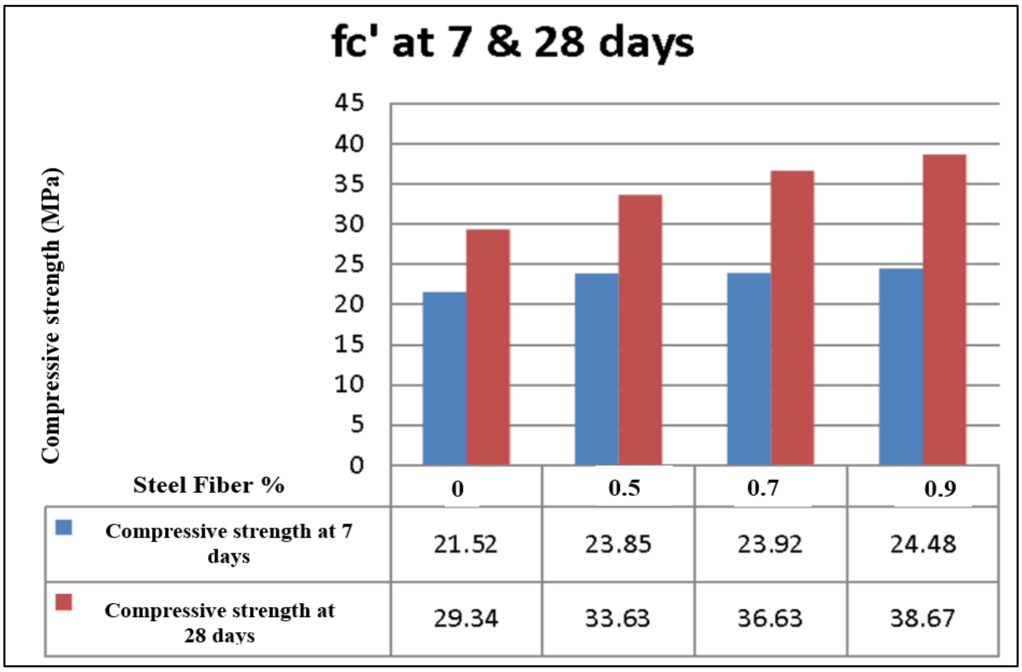

Figure 5. Average compressive strengths of concrete contaian steel fiber at 7 & 28 days

3.2.2. Splitting tensile strength

Tables 12 and 13 demonstrate the splitting tensile strengths of the reinforcement concretes mixtures with steel fiber during 7 and 28 days (14). The concrete's splitting tensile strengths improved with applying of steel fibers, reaching magnitudes of (29, 34, and 69) percent at 7 days, and (1.2, 9, and 45) percent after 28 days with fiber amount of (0.5, 0.7, and 0.9) percent, respectively. Figure 6 depicts the connections between splitting tensile strengths and fiber amount. It has been determined that as the fiber amount grew, so did the tensile strengths.

Table 12. Splitting tensile strengths of steel fiber reinforcement concretes at 7 days

Mix No.	**Types on Concrete**	**Sf %**	**7 days**			**Average splitting tensile strength MPa**
			1	**2**	**3**	
1	NC	zero	1.88	1.60	1.40	1.63
2	A	0.5	2.10	2.04	2.20	2.11
3	B	0.7	2.65	1.96	1.94	2.18
4	C	0.9	2.89	2.95	2.44	2.76

Table 13. Splitting tensile strengths of steel fiber reinforcement concretes at 28 days

Mix No.	**Types on Concrete**	**Sf %**	**28 days**			**Average splitting tensile strength MPa**
			1	**2**	**3**	
1	NC	zero	2.45	2.38	2.71	2.51
2	A	0.5	2.59	2.55	2.48	2.54
3	B	0.7	2.64	2.80	2.76	2.73
4	C	0.9	3.24	3.79	3.90	3.64

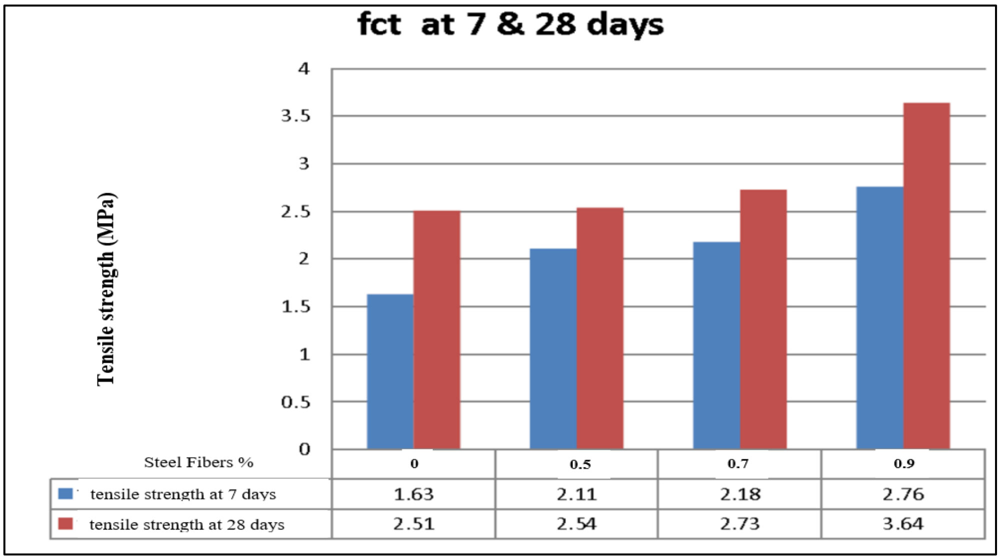

Figure 6. Average concrete's splitting tensile strengths contaian steel fiber at 7 & 28 days

3.2.3. Hardened unit weight

The hardened unit weight has been calculated using the following formula: (ASTM C567-85). The density of concrete was measured using cube samples measuring (15x15x15) cm. The density was calculated in kilograms per cubic meter. It was discovered that increasing the fiber amount does not result in a notable rise in toughened unit weight.

Table 14. Hardened unit weight of steel fiber reinforcement concretes at 28 days

Mix No.	**Types on Concrete**	**Sf %**	**28 days**			**Density** $\frac{Kg}{m^3}$
			1	**2**	**3**	
1	NC	zero	2.38	2.34	2.40	2.37
2	A	0.5	2.47	2.47	2.41	2.45
3	B	0.7	2.43	2.47	2.46	2.45
4	C	0.9	2.52	2.45	2.45	2.47

4. Conclusions

To sum up, adding of fibers (steel type) with various characteristics improves the mechanical characteristics of steel fiber reinforcement concretes greatly. The next findings may be drawn from the provided research work:

- The adding of steel fibers to the conventional concretes resulted in decreased workability. Once combinations are proportioned with greater fiber amounts, such occurrences have been exacerbated.
- The concrete's compressive strengths with different steel fiber amount of (0.5,0.7 and 0.9) % was increased by (10.8,11.1 and 13.7) % at 7 days and (14,25 and 32) % at 28 days.
- The concrete's splitting tensile strength with different steel fiber amount of (0.5,0.7 and 0.9) % was increased by (29, 34 and 69) % at 7 days and (1.2, 9 and 45) % at 28 days.
- There is no noticeable improvement in hardened unit weight with an increase in the fiber amount.

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Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

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