Effect of High Standard of Temperature on the Hardened Needled Concrete

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ABSTRACT

Fibers are usually used to reinforce concrete. The study shows the using of needles for reinforcing high-strength concrete (60MPa) when the samples are exposed to temperatures (100°C and 400°C) with a percentage of needles (0%, 0.5% and 1%) compared with the conditions of room temperature (25°C).

They study shows that the compressive strength decreases by about (0.94% and 17.6%) for (0% needle (steel fiber)) at 100°C and 400°C, respectively. The compressive strength decreases by about (1.7% and 15.9%) for (0.5% needle (steel fiber)) at100°C and 400°C, respectively. The compressive strength decreases by about (0.3% and 14.2%) for (1% needle (steel fiber)) at 100°C and 400°C, respectively. All the above-mentioned results are compared with cubes tested at room temperature (25°C).

Based on the results of this work, the tensile strength decreases by about (0.49% and 6.65%) for (0% needle (steel fiber)) at 100°C and 400°C, respectively. The tensile strength decreases by about (0.73% and 6.1%) for (0.5% needle (steel fiber)) at 100°C and 400°C, respectively. The tensile strength decreases by about (0.24% and 5.54%) for (1% needle (steel fiber)) at 100°C and 400°C, respectively. All the above-mentioned results are compared with cubes tested at room temperature (25 °C).

The flexural strength decreases by about (1.08% and 26%) for (0% needle (steel fiber)) at 100°C and 400°C, respectively. The flexural strength decreases by about (2.1% and 26.3%) for (0.5% needle (steel fiber)) at 100°C and 400°C, respectively. The flexural strength decreases by about (3.1% and 24.7%) for (1% needle (steel fiber)) at 100°C and 400°C, respectively. All the above-mentioned results are compared with cubes tested at room temperature (25°C).

KEYWORDS: Steel fiber, Hardened concrete, High strength, Elevated temperature.

INTRODUCTION

Plain (unreinforced concrete) is a brittle material, with a low tensile strength and a low strain capacity. Adding short needle-like fibers to such matrices enhances their mechanical properties, particularly their toughness, ductility and energy absorbing capacity under impact (Naaman, 2003; Wei and Ran, 2008).

Most common steel fibers are round in cross-section with diameters ranging from 0.4 to 0.8 mm and lengths ranging from 25 to 60 mm. Their aspect ratio; that is, the ratio of length over diameter or equivalent diameter, is generally less that 100, with a common range from 40 to 80. Generally in concrete applications, the aspect ratio of very fine fibers exceeds 100, while that of courser fibers is less than 100, when very low volume content is used such as for the control of plastic shrinkage cracking (Naaman, 2003; Wei and Ran, 2008).

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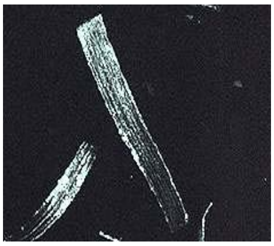
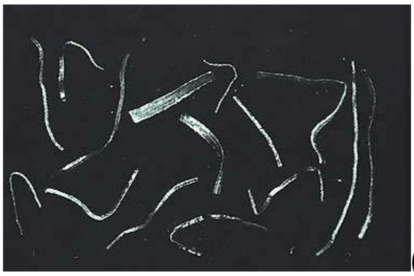
Developing better bond between the fiber and the matrix can be achieved along its length by roughening its surface. Thus, fibers can be smooth or deformed typical examples of steel fibers as shown in Figure (1) (Naaman, 2003). The cross-section of the fiber can be circular, rectangular, square, triangular, flat and polygonal as shown in Figures (2a &b) (Lie and Kodur, 1996). When short steel fiber with not less than 1% volume is combined with long steel fiber to reach 2% volume of steel fibers in concrete, the flowability of the fresh concrete does not depend on the increase of long steel fiber. Short steel fiber content has a high influence on the properties of concrete. The increase of short steel fiber reduces flowability but improves flexural strength (Lie and Kodur, 1996).

Figure 1: Typical Example of Steel Fibers



(a)



(b)

Figure 2: Shape of Steel Fiber

The Effect of Fiber on Hardened Concrete Properties

Fibers do little to enhance the static compressive strength of concrete, with increases in strength ranging from essentially nil to perhaps 25%. Even in members which contain conventional reinforcement in addition to the steel fibers, the fibers have little effect on compressive strength. However, the fibers do increase the cracking ductility, or energy absorption of the material. Steel fibers are generally found to have aggregate much greater effect on the flexural strength of SFRC than on either the compressive or tensile strength, with increases of more than 100% having been reported. The increase in flexural strength is particularly sensitive, not only to the fiber volume, but also to the aspect ratio of the fibers, with higher aspect ratio leading to larger strength increases (Kraig, 1984; Huy, 2008).

The properties of fiber, volume fraction of steel fiber and aspect ratio affect the compressive strength results. Flexural strength is improved by the addition of steel fibers. The combination of short and long steel fiber in which short steel fiber isn't less than 1% volume is necessary to manufacturing concrete with an optimal mechanical performance (Cowper and Symonds, 1999).

The Thermal Properties of Steel Fiber

The thermal properties of steel fibers are presented in equations that express the values of these properties as a function of temperature in the temperature range 0-1000°C. The mechanical properties are given in the form of stress - strain relationships for concretes at elevated temperatures. The results indicate that the steel fibers have little influence on the thermal properties of concretes. The influence on the mechanical properties, however, is relatively greater than the influence on the thermal properties, which is expected to be beneficial to the fire resistance of structural elements constructed of fiber-reinforced concrete (Guerrero and Guerrero, 1999; Song and Shen, 2005):

1- The compressive strength at elevated temperatures of fiber-reinforced concrete is higher than that of plain concrete. The presence of steel fibers increases the ultimate strain and improves the ductility of a fiber-reinforced concrete member.
2- Steel fiber reinforced concrete exhibits, at elevated temperatures, mechanical properties that are more beneficial to fire resistance than those of plain concrete.
3- Steel fiber reinforced concrete exhibits, at elevated temperatures, thermal properties that are similar to those of plain concrete.

EXPERIMENTAL WORK

Materials

Optimum proportions for conventional concrete (CC) were selected according to the mix design methods, considering the characteristics of all the materials used. Satisfactory CC is achieved by selecting suitable materials, good quality control and proportioning.

Cement

The proper selection of the type and source of cement is one of the most important steps in the production conventional concrete, especially Ordinary Portland Cement (OPC) (Type I). This cement is manufactured in Iraq by Taslooja factory and commercially known as (Taslooja). Table (1) shows the chemical and physical properties for Ordinary Portland Cement (OPC) (type I). These properties of cement comply with the Iraqi Standard Specification (I.Q.S. No.5, 1984) requirements.

Water

Ordinary potable water is used without any additives.

Coarse Aggregate

Crushed gravel of maximum size of 14mm from Al-Niba'ee region is used. Table (2) shows the grading of this aggregate after sieving on 14mm sieve to remove particles with size greater than 14mm, specific gravity of 2.65, sulfate content of 0.09 % and absorption of 0.60 %. This coarse aggregate conforms to the (Iraqi specification No.45, 1984).

Fine Aggregate

The grading, particle shapes and the amount of fine aggregate are important factors in the production of conventional concrete. Natural sand from Al-Ukhaider region is used. Table (3) shows the grading of the fine aggregate with specific gravity of 2.60, sulfate content of 0.35% and absorption of 0.73%. This fine aggregate conforms to the (Iraqi specification No.45, 1984).

Superplasticizer

For the production of high strength conventional concrete with steel fiber, the superplasticizer (Glenium 51) based on polycarboxylic ether is used. Glenium 51 is free of chlorides and complies with ASTM C494, type A and type F. It is compatible with all Portland cements that meet the recognized international standards.

Mix Design for Conventional Concrete

Conventional concrete strength with needle (steel fiber) is investigated in this work; namely 60 MPa. British Standard BS 5328: part 2: 1991 mix design method is used in this work due to its wide range of strengths. The details of the mix are shown in Table (4).

Table 1[*]. Chemical and Physical Properties of (Taslooja) for Ordinary Portland Cement Type (I)

Chemical Composition			IQS 5:1984 Limits
Oxides		%	
Calcium oxide	CaO	60.92	
Silicon dioxide	SiO_2	21.88	
Aluminum oxide	Al_2O_3	3.96	
Ferric oxide	Fe_2O_3	4.28	
Magnesium oxide	MgO	3.15	5.00 max.
Sulfur trioxide	SO_3	2.46	2.50 max.
Loss on Ignition	L.O.I.	2.09	4.00 max.
Insoluble residue	I.R.	0.60	1.50 max.
Lime saturation factor	L.S.F.	0.86	0.66 -1.02
C3A		3.26	3.5 max.

Physical Properties	Test Result	IQS 5:1984
Fineness: specific surface, Blaine (cm^2/gm)	288	250 max.
Soundness	0.17	0.8 max.
Setting time, Vicat's method:		
Initial (min)	66	45 min.
Final (hrs:min)	3:26	10 max.
Compressive strength of cement		
3 days	24.10	15 min.
7 days	36.20	23 min.
28 days	52.00	-----

* Tests of cement were conducted at the National Center for Construction Laboratories and Research.

Table 2. Grading of Coarse Aggregate

Sieve Size (mm)	% Passing by Weight	
	%Coarse Aggregate Passing	Limits of Iraqi Specification No.45/1984
20	100	100
14	99.00	90-100
10	60.90	50-85
5	5.50	0-10
2.36	0	------

Testing for Hardened Concrete

After testing the fresh properties, the concrete was poured in the moulds. For testing the compressive strength and tensile strength, 27 cubes of size (150mm) and 27 cylinders of size (150X300) mm were used according to (BS 1881: part108, 1983) and (ASTM C496-96), respectively, while 18 prisms of size (100X100X500) mm were cast for testing in flexure according to (ASTM C78-84). When conventional concrete is used, the specimens are fully compacted on a vibrating table. The vibration time to reach full compacting is decided upon by the stop of air bubble migration from fresh concrete, which is found to be 25-30 seconds per layer.

Table 3. Grading of Fine Aggregate

Sieve Size (mm)	% Passing by Weight	
	%Fine Aggregate Passing	Limits of Iraqi Specification No.45/1984 for Zone2
10	100	100
4.75	94.00	90-100
2.36	89.50	75-100
1.18	75.00	55-90
0.6	44.60	35-59
0.3	10.80	8-30
0.15	0.05	0-10
Fineness of Modulus = 2.93		

Table 4. Details of Conventional Concrete Mix

Mix	W/C Ratio	Water kg/m^3	Cement kg/m^3	Sand kg/m^3	Gravel kg/m^3	%SP by weight of cement	% Steel fiber by weight of mix
C60	0.36	160	446	762	1050	2	**0**
							0.5
							1

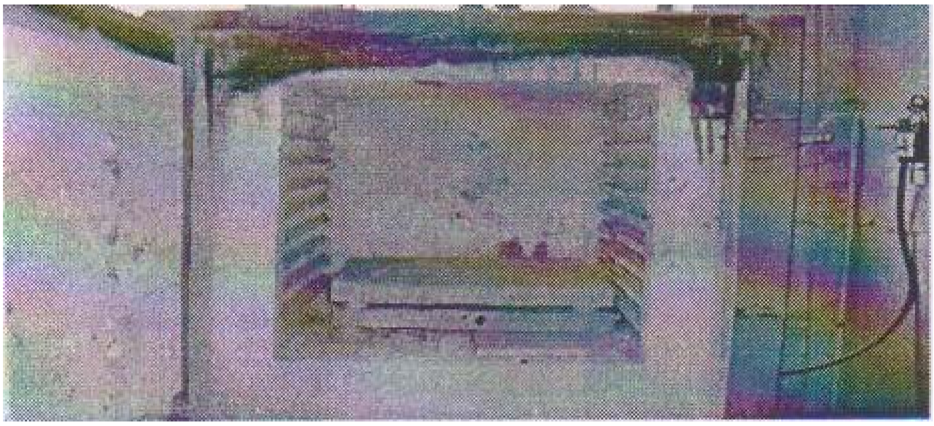


Figure 3: The Furnace Used

Table 5. Compressive Strength Results at Different Temperatures

Mix	Steel Fiber %	Compressive Strength at 25°C (MPa)	Compressive Strength at 100°C (MPa)	Compressive Strength at 400°C (MPa)
C 60	0	62.59	62.00	51.6
	0.5	64.22	63.11	54
	1	66.4	66.2	57

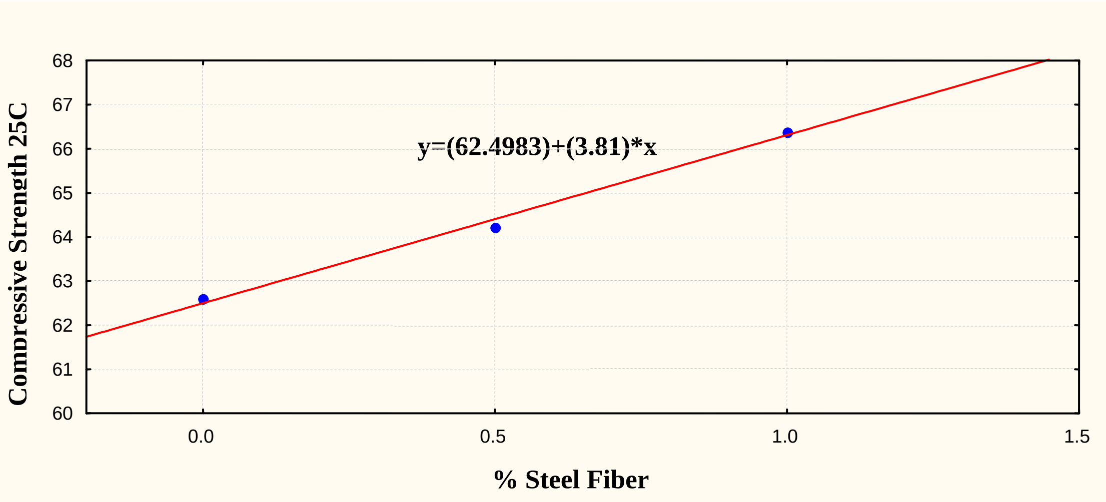


Figure 4: Compressive Strength *versus* Percentage of Steel Fiber at 25°C

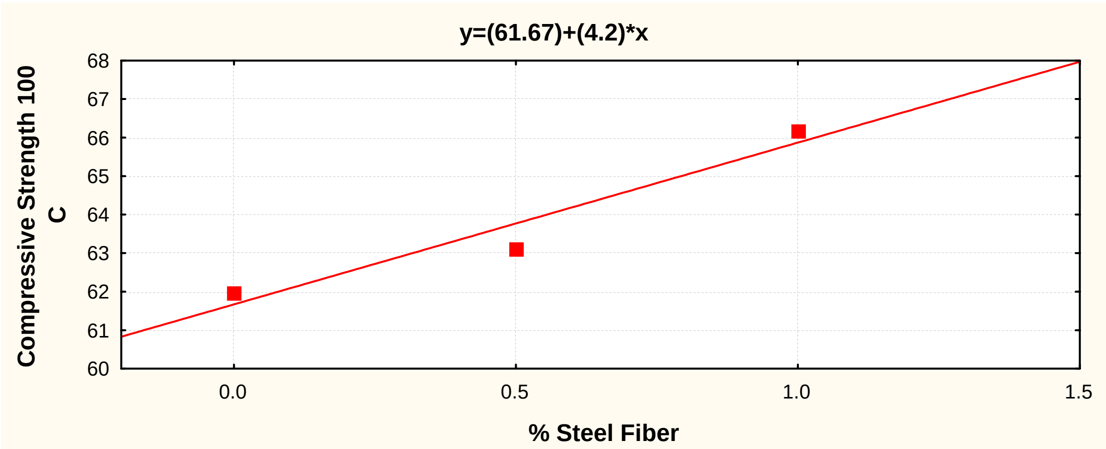


Figure 5: Compressive Strength *versus* Percentage of Steel Fiber at 100°C

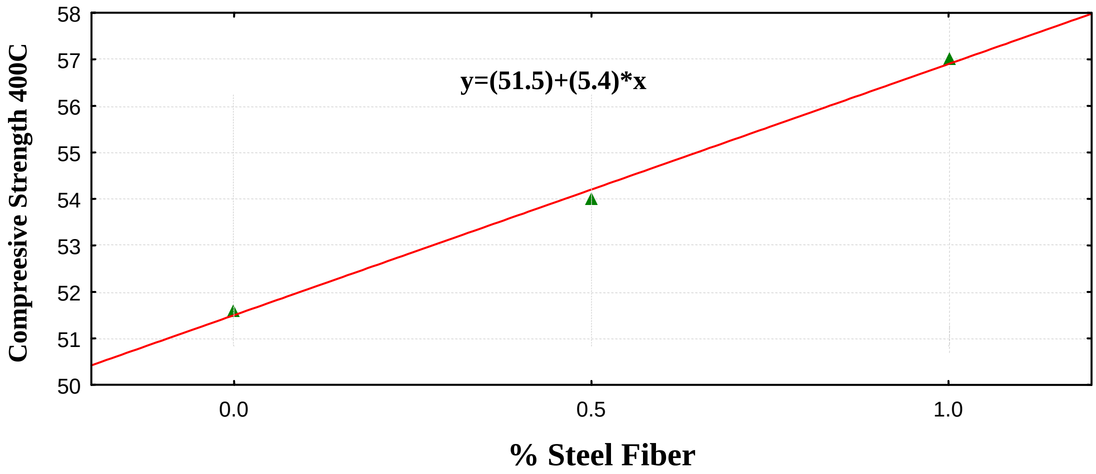


Figure 6: Compressive Strength *versus* Percentage of Steel Fiber at 400°C

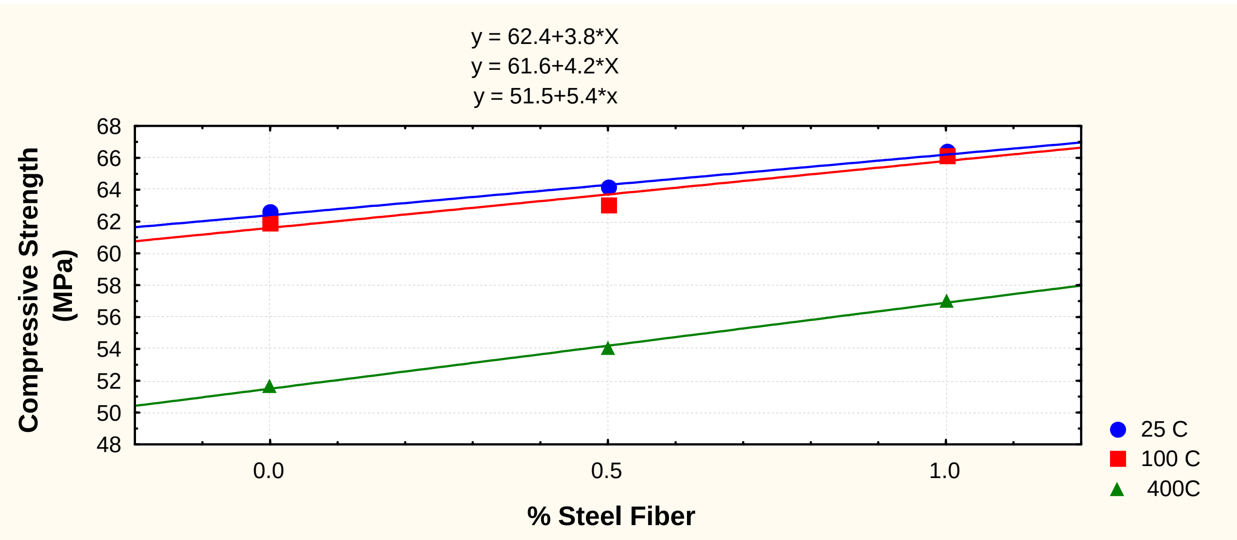


Figure 7: Compressive Strength *versus* Percentage of Steel Fiber at All Level Temperatures

Table 6. Results of Tensile Strength

Mix	Steel Fiber %	Tensile Strength at 25°C (MPa)	Tensile Strength at 100°C (MPa)	Tensile Strength at 400°C (MPa)
C 60	0	4.06	4.04	3.79
	0.5	4.10	4.07	3.85
	1	4.15	4.14	3.92

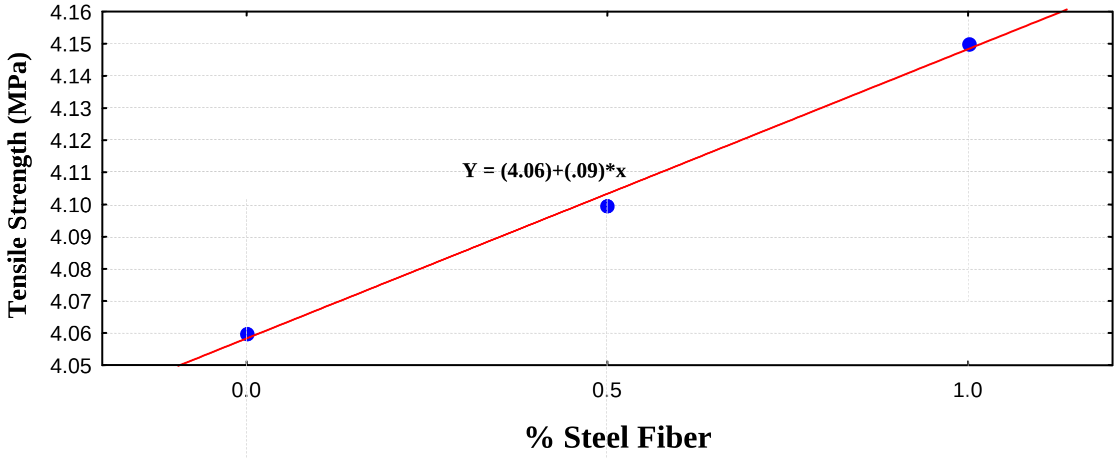


Figure 8: Tensile Strength *versus* Percentage of Steel Fiber at 25°C

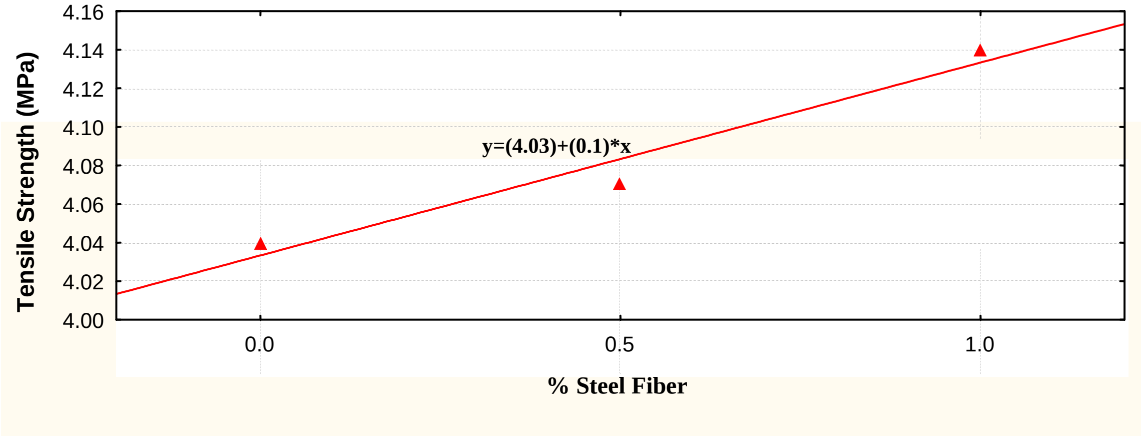


Figure 9: Tensile Strength *versus* Percentage of Steel Fiber at 100°C

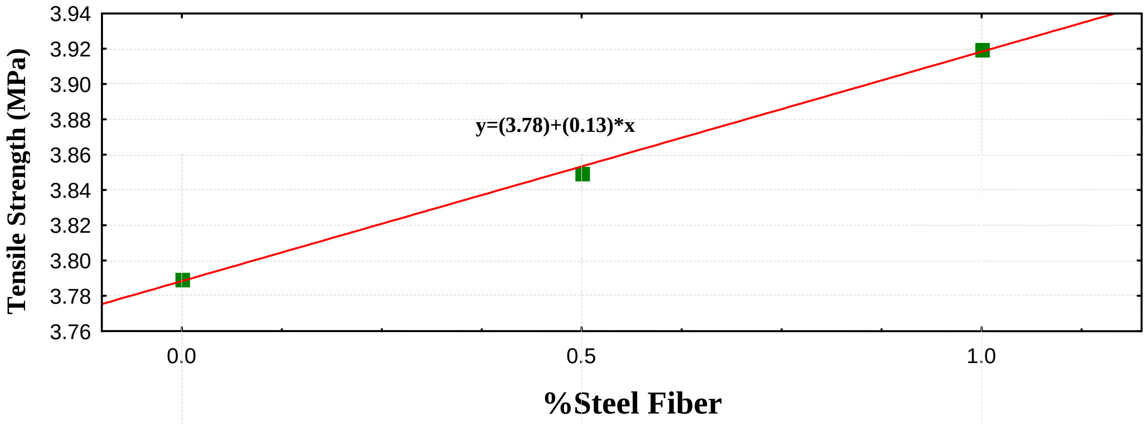


Figure 10: Tensile Strength *versus* Percentage of Steel Fiber at 400°C

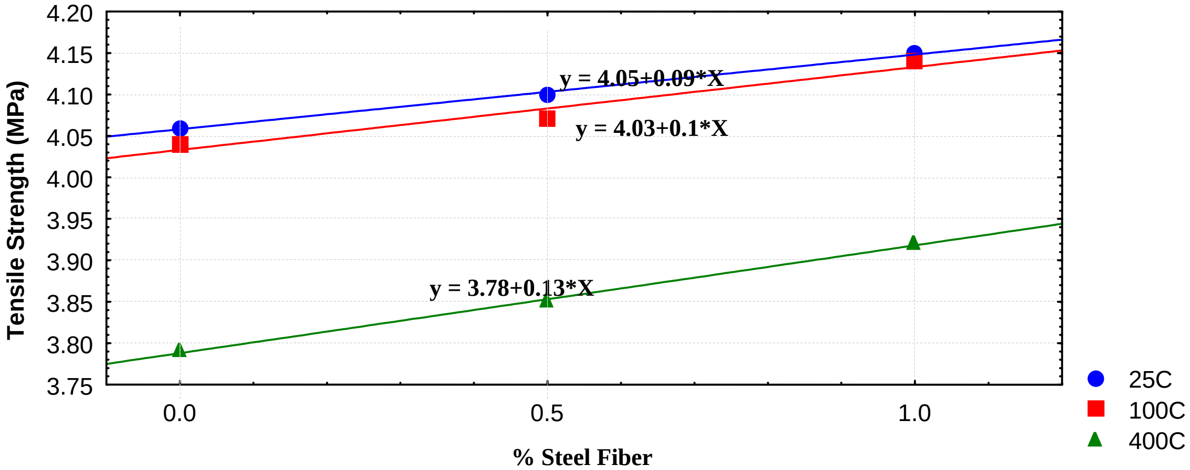


Figure 11: Tensile Strength *versus* Percentage of Steel Fiber at all Level Temperatures

Table 7. Results of Flexural Strength

Mix	Flexural Strength at 25°C(MPa)	Flexural Strength at 100°C(MPa)	Flexural Strength at 400°C(MPa)	%Steel Fiber
C 60	9.2	9.1	6.8	0
	9.5	9.3	7.0	0.5
	9.7	9.4	7.3	1

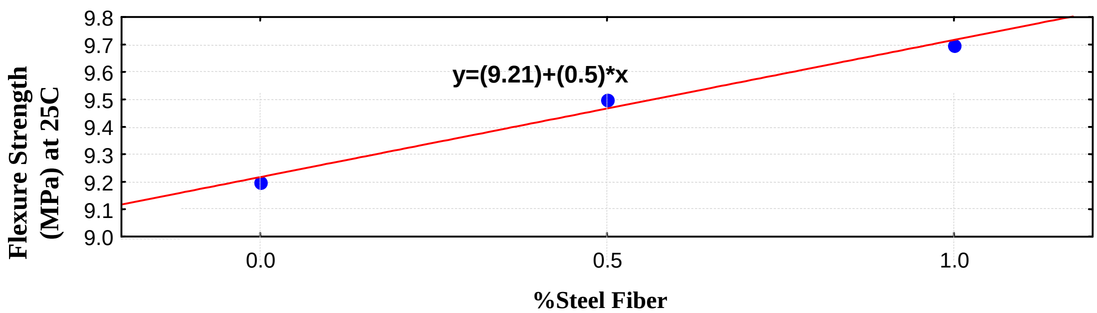


Figure 12: Flexural Strength *versus* Percentage of Steel Fiber at 25°C

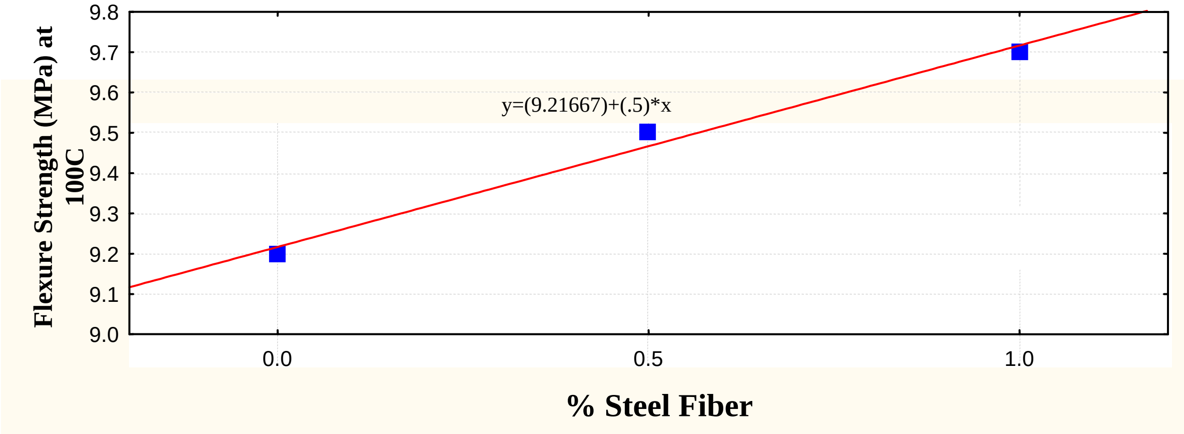


Figure 13: Flexural Strength *versus* Percentage of Steel Fiber at 100°C

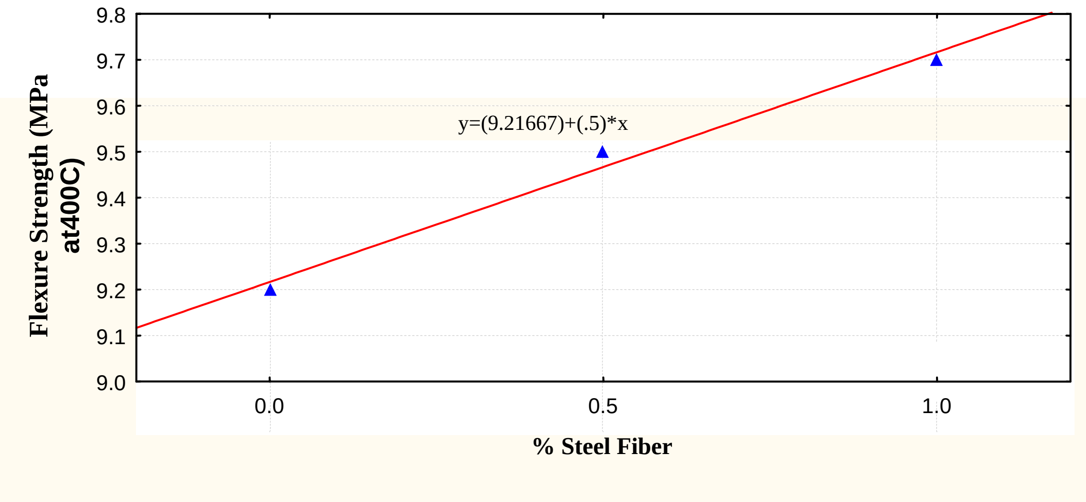


Figure 14: Flexural Strength *versus* Percentage of Steel Fiber at 400°C

The specimens were demolded and put in water for 28 days for curing. After the period of curing, the stored (cubes, cylinders and prisms) were subjected to a high temperature in an electric furnace to study the effect of elevated temperature (100 and 400°C) and compared with the specimens still at room temperature (25°C). The electric furnace used for heating all the specimens is shown in Figure (3). The furnace was switched off and the specimens were allowed to cool for 24 hours to ensure complete cooling of the specimens.

RESULTS AND DISCUSSION

General

The results obtained from the experimental work are analyzed and studied. This study includes the effect of elevated temperature on (compressive, tensile and flexure) strength of needle (steel fiber) in high strength concrete. The results are analyzed by using *statistica* software.

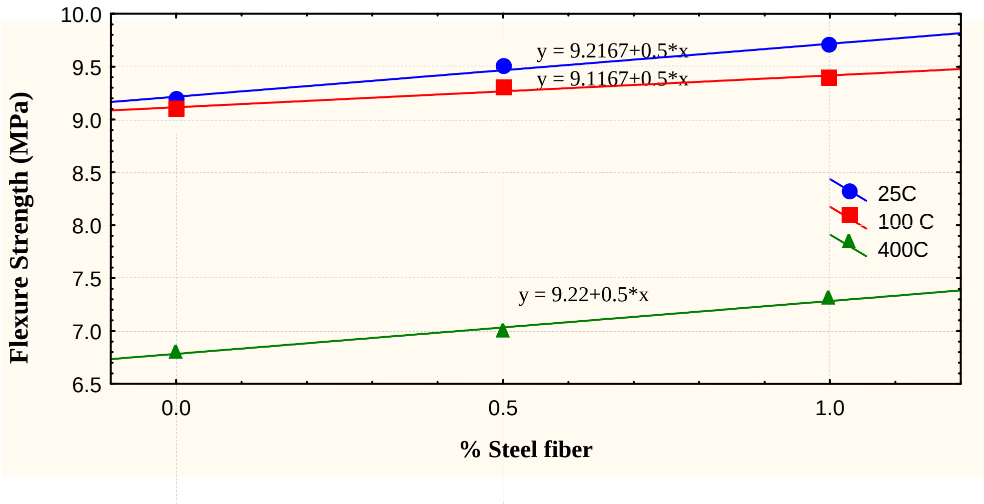


Figure 15: Flexural Strength *versus* Percentage of Steel Fiber at All Level Temperatures

Compressive Strength

The results of compressive strength for conventional concrete are shown in Table (5) at 28 days. In this study, three cubes of (150X150X150)mm were used with each level of heating. Figures (4) to (7) show the relation between compressive strength and percentage of needle (steel fiber).

Tensile Strength

The results of tensile strength for conventional concrete are shown in Table (6) at 28 days. In this study, three cylinders of (150X300) mm were used with each level of heating. Figures (8) to (11) show the relation between tensile strength and percentage of needle (steel fiber).

Flexural Strength

The results of flexural strength for conventional concrete are shown in Table (7) at 28 days. In this study three prisms of (100X100X500) mm were used with each level of heating. Figures (12) to (15) show the relation between flexural strength and percentage of needle (steel fiber).

CONCLUSIONS

Based on the experimental results, the following conclusions can be drawn:

1. The compressive strength decreases by about (0.94% and 17.6%) for (0% steel fiber) at 100ºC and 400ºC, respectively, but the compressive strength decreases by about (1.7% and 15.9 %) for (0.5% steel fiber) at 100ºC and 400°C, respectively, while for (1% steel fiber), the compressive strength decreases by about (0.3% and 14.2%) at 100ºC and 400ºC, respectively.
2. The tensile strength decreases by about (0.49% and 6.65%) for (0% steel fiber) at 100ºC and 400ºC, respectively, and the tensile strength decreases by about (0.73% and 6.1%) for (0.5% steel fiber) at 100ºC and 400ºC, respectively, while the tensile strength decreases by about (0.24% and 5.54%) for (1% steel fiber) at 100ºC and 400ºC, respectively.
3. The flexural strength decreases by about (1.08% and 26%) for (0% steel fiber) at 100ºC and 400ºC, respectively. The flexural strength decreases by about (2.1% and 26.3%) for (0.5% steel fiber) at

100ºC and 400ºC, respectively. For (1% steel fiber), the flexural strength decreases by about (3.1% and 24.7%) at 100ºC and 400ºC, respectively.

All the above results are compared with cubes tested at room temperature (25ºC).

4. These results are consistent to the rule that, high strength concrete is more sensitive to high temperature because of its reduced porosity.

REFERENCES

ASTM C496-96. Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, American Standards Society for Testing and Materials.

ASTM C78-84. Test Method for Flexural Strength of Concrete, American Standards Society for Testing and Materials.

BS 1881: Part 108. 1983. Method for Making Test Cubes from Fresh Concrete, British Standard Institute.

Cowper, G.R. and Symonds, P.S. 1999. Strain Hardening and Strain Rate Effect in the Impact Loading of Cantilever Beams, Brown University, Division of Applied Mathematics Report, 28.

Craig, R.J. 1984. Structural Applications of Reinforced Steel Fibrous Concrete. *Concrete Int. Design and Construction*.

Guerrero, A.E. and Guerrero, P.A. 1999. Effect of Mechanical Clamping on the Pull-out Response of Hooked Steel Fibers Embedded in Cementitious Matrices. *Concrete Science and Engineering,* January, 15-25.

Huy, Kim. 2008. Influence of Types of Steel Fiber on Properties of Ultra High Performance Concrete, *ACF International Conference*, 374.

Iraqi Standard Specification No.5 (Portland Cement). 1984. Central Apparatus for Standardization and Control, Baghdad, 8.

Iraqi Standard Specification No.45 (Natural Sources Residues Used in Concrete and Construction). 1984. Central Apparatus for Standardization and Control, Baghdad.

Lie, T.T. and Kodur, V.R. 1996. Thermal and Mechanical Properties of Steel-Fibre-Reinforced Concrete at Elevated Temperatures, *Canadian Journal of Civil Engineering*, 23 (April): 511-517.

Naaman, A.E. 2003. Engineered Steel Fibers with Optimal Properties for Reinforcement of Cement Composites, *Journal of Advanced Concrete Technology*, 1 (3): 241-252, November, Japan Concrete Institute.

Song, P.S. and Shen, B.C. 2005. Assessment of Statistical Variations in Impact Resistance of High-strength Concrete and High-strength Steel fiber-Reinforced Concrete, *Cement and Concrete Research*, 35: 393-399.

Wei, L. and Ran, H. 2008. Effect of Steel Fiber on the Mechanical Properties of Cement-based Composites Containing Silica Fume, *Journal of Marine Science and Technology*, 16 (3): 214-221.