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# *Effect of Steel Fiber and Silica Fume on Hardened Concrete Compressive and Flexural strength*

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## Abstract:

*Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers and silica fume. In this paper an attempt is made at 300℃ to present the results of an experimental investigation carried out on (FRC). While Fiber content was used as (0%, 0.5% and1%) by weight of mix and silica fume was used as (0%, 5% and 10%) by weight of cement. Effect of the addition of silica fume and steel fiber on the various strengths of concrete was studied. The strengths considered for investigation are compressive strength and flexural strength. Cubes of size (150) mm for compressive strength; beams of size (100 mm x 100 mm x 500 mm) for flexural strength, were used as specimens. All the specimens were water cured for 28 days and tested subsequently. The compressive strength decreases by about (18%, 18.1% , 20% ) for (0% steel fiber) at 300℃ with no silica fume, 5% and 10% silica fume respectively and the compressive strength decreases by about (16%, 20 % , 24% ) for (0.5% steel fiber) at 300℃ with no silica fume, 5% and 10% silica fume respectively while the compressive strength decreases by about (15%, 15.5%, 16% ) for (1% steel fiber) at 300℃ with no silica fume, 5% and 10% silica fume respectively. The flexure strength decreases by about (40.3%, 39.9% , 41% ) for (0% steel fiber) at 300℃ with no silica fume, 5% and 10% silica fume respectively and the flexure strength decreases by about (38.5%, 38.0% , 38.1%) for (0.5% steel fiber) at 300℃ with no silica fume, 5% and 10% silica fume respectively, while flexure strength decreases by about (35.8%, 36%, 37.07% ) for (1% steel fiber) at 300℃ at 300℃ with no silica fume, 5% and 10% silica fume respectively. All the above results are compared with cubes and prisms tested at room temperature (25 ℃).*

*Keywords: fiber reinforced concrete (FRC), Silica fumes, Steel fibers.*

# تأثير ألياف  وغبار السليكا على مقاومه الانضغاط والانحناء للخرسانة المتصلبة

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## الخلاصة :

***تعرف الخرسانة المقواة بالياف الفايبر على انها خرسانة مركبة مكونة من مزيج من السمنت، الحصى، الرمل، الياف الفايبر وغبار السيليكا .***

***يهدف هذا البحث الى تقييم اداء الخرسانة المقواة بالياف الفايبر وغبار السيليكا من حيث مقاومة الانضغاط والانثناء للخرسانة في درجة حرارة 300°م .لاجراء هذه التجربة استخدم مكعب ذو ابعاد ( 150×150) ملم وموشور ذو ابعاد (100×100×500) ملم.***

***وجدت النتائج ان مقاومة الانضغاط للخرسانة قلت بحدود (18٪، 18,1٪، 20٪) في حالة(0٪ الياف الفايبر) في درجة حرارة 300°م وغبار السيليكا( 0٪، 5٪، 10٪) على التوالي ، قلت مقاومة الانضغاط بحدود (16٪، 20٪، 24٪) في حالة (0,5٪ الياف الفايبر) في درجة حرارة 300°م وغبار السيليكا ( 0٪، 5٪، 10٪) و قلت مقاومة الانضغاط بحدود ( 15٪، 15,5٪، 16٪) في حالة (1٪ الياف الفايبر) في درجة حرارة 300°م وغبار السيليكا ( 0٪، 5٪، 10٪). كما وجد ان مقاومة الانثناء للخرسانة قلت بحدود (40,3٪، 39,9٪، 41٪) في حالة (0٪ الياف الفايبر) في درجة حرارة 300°م وغبار السيليكا( 0٪، 5٪، 10٪) على التوالي ، قلت مقاومة الانثناء بحدود (38,5٪، 38٪، 38,1٪) في حالة (0,5٪ الياف الفايبر) في درجة حرارة 300°م وغبار السيليكا ( 0٪، 5٪، 10٪) و قلت مقاومة الانثناء بحدود ( 35,8٪، 36٪، 37,07٪) في حالة (1٪ الياف الفايبر) في درجة حرارة 300°م وغبار السيليكا ( 0٪، 5٪، 10٪). علما ان جميع النتائج قد تم مقارنتها مع مكعبات ومواشير بدرجة حرارة (25°).***

## Introduction:

Strength of concrete was all among considered as a governing factor in the various types of concrete applications, because all the other properties were assumed to be related to the strength. However, now, more stresses is being laid on the performance criteria of concrete [1]. 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 medical properties, particularly their toughness, ductility and energy absorbing capacity under impact [2, 3].

The last four decades have seen a large number of research studies on fiber reinforced concrete, most of  which devoted to the use of steel fibers. According to the fiber material: natural organ (such as cellulose), steel, titanium, glass, carbon, polymers according to **Figure (1)**, [2]. The cross section of the fiber can be circular, rectangular, square, triangular, flat, and polygonal [3]. Fillers and pozzolanic materials are introduced to improve the strength and other properties of concrete for necessary conditions.

Silica fume (pozzolanic material) is produced from burning of powdered coal in power plants. It is also known as micro-silica. It is a byproduct of silicon metal and ferrosilicon. The material is a very fine powder with spherical particles about 100 times smaller in size than Portland cement.

The use of pozzolanic material in concrete is an old age concept. Pozzolanic materials can be used to replace a part of cement in all construction works. Silica fume can be successfully used in concrete due to the advantages over ordinary plain concrete, such as increased compressive strength, improved workability, reduced permeability, reduced shrinkage, less bleeding and more economicality [4].

The following points show the properties of concrete improved by Steel Fibers and Silica Fume [5]:

1. The fibers can increase the toughness of the concrete.
2. The fibers tend to increase the strain at peak load.
3. Fibers in concrete can be expected to improve the resistance of conventionally reinforced structural members to cracking, deflection and serviceability conditions.
4. Impact resistance: greater resistance to damage in case of a heavy impact.
5. Permeability: the material is less porous.
6. Shrinkage cracks can be eliminated.
7. Workability: With the addition of silica fume, the slump loss with time is directly proportional to increase in the silica fume content due to the introduction of large surface area in the concrete mix by its addition. Although the slump decreases, the mix remains highly cohesive.
8. Segregation and Bleeding: Silica fume reduces bleeding significantly because the free water is consumed in wetting of the large surface area of the silica fume and hence the free water left in the mix for bleeding also decreases.

**Fig . (1) Steel fiber in Concrete.**

## Experimental work:

### Program of work

This research was designed to study the effect of steel fiber and silica fume on compressive strength and flexural strength of high strength concrete.

In this study nine concrete mixes with different percentage of steel fiber and silica fume. In each mix used three cubes of (150*150*150) mm, three prisms of (100*100*500) mm and tested with each level of heating.

## Materials and mixes

Optimum proportions for conventional concrete (CC) must be 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) (typeI). This cement is manufactured in Iraq by Taslooja factory and commercially known (Taslooja). **Table (1)** and **Table (2)** show chemical and physical properties for Ordinary Portland cement (OPC) (type I). These properties of cement comply with Iraqi Standard Specification I.Q.S. No.5, 1984 requirement [6].

**Table .(1) Chemical Composition of Cement**

| Oxides | | % * | IQS 5:1984 Limits |
|---|---|---|---|
| Calcium oxide | CaO | 62.44 | |
| Silicon oxide | $SiO_2$ | 20.25 | |
| Aluminum oxide | $Al_2O_3$ | 4.73 | |
| Ferric oxide | $Fe_2O_3$ | 4.32 | |
| Magnesium oxide | MgO | 2.19 | 5 max. |
| Sulphur trioxide | $SO_3$ | 1.88 | 2.8 max. |
| Loss on Ignition | L.O.I | 3.5 | 4.00 max. |
| Insoluble residue | I.R | 1.33 | 1.5 max |
| Lime saturated factor | L.S.F | 0.86 | 0.66- 1.02 |
| C3A | | 8.10 | |

***All tests were made in the National Center for Construction Laboratories and Research*.**

**Table .(2) Physical Properties of Cement**

| Physical properties | Test result* | IQS 5:1984 limits |
|---|---|---|
| Fineness: specific surface, Blaine cm²/gm | 3372 | 2300 min |
| Setting time, Vicat's method:- | | |
| Initial (hrs: min.) | 1:35 | 45 minutes min. |
| Final (hrs :min) | 3:50 | 10 hrs max. |
| Compressive strength of cement mortar cubes (70.7mm) MPa | | |
| 3 days | 24.30 | 15 min. |
| 7 days | 27.5 | 23 min. |

***All tests were made in the National Center for Construction Laboratories and Research.***

## Water:

Ordinary potable water is used without any additives.

## Fine Aggregate:

The grading, particle shapes and the amount of fine aggregate is 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 and the limits of the Iraqi specification No.45/1984 [7]. Specific gravity, sulfate content and absorption of 2.6, 0.32% and 0.75 % respectively is used in this work performed in the Laboratory of Materials in the Engineering College of Al-Mustansyriah University**.**

**Table .(3) Grading of Fine Aggregate.**

| Sieve Size (mm) | % Passing by Weigh | |
|---|---|---|
| | %Fine Aggregate Passing | Limits of Iraqi Specification No.45/1984 for Zone2 |
| 10 | 100 | 100 |
| 4.75 | 93.40 | 90-100 |
| 2.36 | 85.40 | 75-100 |
| 1.18 | 75.60 | 55-90 |
| 0.6 | 41.70 | 35-59 |
| 0.3 | 9.10 | 8-30 |
| 0.15 | 0.04 | 0-10 |
| Fineness of Modulus = 2.95 | | |

## Coarse Aggregate:

Crushed gravel of maximum size of 14mm from Al-Niba'ee region is used. **Table (4)** shows the grading of this aggregate after sieving on 14mm sieve to remove particles with size greater than 14mm. This coarse aggregate conforms to the Iraqi specification No.45/1984 [7]. Specific gravity, sulfate content and absorption of 2.64, 0.09% and 0.63 % respectively is used in this work performed in the Laboratory of Materials in the Engineering College of Al-Mustansyriah University.

**Table .(4) Grading of Coarse Aggregate.**

| Sieve Size (mm) | % Passing by Weight | |
|---|---|---|
| | %Coarse Aggregate Passing | Limits of Iraqi Specification No.45/1984 |
| 20 | 100 | 100 |
| 14 | 99.10 | 90-100 |
| 10 | 57.90 | 50-85 |
| 5 | 4.20 | 0-10 |
| 2.36 | 0 | ------ |

## Fibers

Hooked-End Steel Fibres were used in this investigation with volumetric ratio (0, 0.5 and1) % and the properties of these fibers are presented in **Table (5).**

**Table (5): Properties of steel fibers *.**

| Tensile strength(MPa) | Length (mm) | Diameter (mm) | Density (kg/m$^3$) | L/d |
|---|---|---|---|---|
| 1050/1150 | 30 | 0.5 | 7860 | 60 |

***From Manufacturer Catalogue***

### Silica fume

The silica fume used in the mixes had a chemical and physical properties are shown in Table (6) and (7).

**Table .(6) Chemical Analysis of Silica Fume.**

| Oxide composition | * Oxide content % |
|---|---|
| $SiO_2$ | 86.46 |
| Al2O3 | 1.6 |
| Fe2O3 | 1.11 |
| Na2O | 0.3 |
| K2O | 1.9 |
| CaO | 1.8 |
| MgO | 1.9 |
| SO3 | 0.25 |
| L.O.I. | 4.02 |

***Tests were carried out at the General Company of Geological Surveying and Mining***

**Table .(7) Physical Properties of Silica Fume**

| Requirement | * Analysis % | Limit of requirements according ASTM C 1240 |
|---|---|---|
| Moisture content | 0.68 | <3.0 |
| Percent Retained on 45-μm (No.325) Sieve, Max. | 7 | <10 |
| Accelerated Pozzolanic Strength Activity Index with Portland Cement at 7 days, Min. Percent of Control | 128.6 | >105 |
| Specific Surface, Min, $m^2$/kg | 21000 | >15000 |

***Tests were carried out at the General Company of Geological Surveying and Mining***

### Superplasticizer:

For the production of high strength conventional concrete with steel fiber, superplasticizer (high water reducing agent HWRA) based on polycarboxylic ether is used. The typical properties of Glenium 51 are shown in **Table (8).**

**Table .(8) Typical Properties of Glenium 51.**

| | |
|---|---|
| Form | Viscous Liquid |
| Colour | Light Brown |
| Relative Density | 1.1 @ 20 $^0$C |
| pH | 6.6 |
| Viscosity | 128+/-30 cps @ 20 $^0$C |
| Transport | Not Classified as Dangerous |
| Labeling | No Hazard Label Required |

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 steel fiber and silica fume is investigated in this work, namely 40 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 (9).**

## Mixing Procedure for Conventional Concrete:

Mixing method is important to obtain the required workability and homogeneity of concrete mix. Concrete is mixed in drum laboratory mixer, with a capacity of 0.3m$^3$. Initially, coarse aggregate and fine aggregate are poured into the mixer, followed by 50% of the mixing water to wet them. The cement and silica fume is added at this stage, followed by 25% of the mixing water, and then the remaining 25% of the water is added gradually to the mix. After this stage, the superplastisizer is mixed gradually with that main mix, and during this process steel fibers are added. The total mixing time is in the range of (4-6) minutes.

**Table .(9) Details of Conventional Concrete Mix.**

| Mix | w/p Ratio | Water kg/m$^3$ | Cement kg/m$^3$ | Sand kg/m$^3$ | Gravel kg/m$^3$ | SP l/ 100 kg of cement | silica fume | | % Steel fiber by weight of mix |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | % of cement | kg/m$^3$ | |
| C40 | 0.36 | 160 | 440 | 760 | 1050 | 2 | 0 | 0 | 0 |
| | | | | | | | | | 0.5 |
| | | | | | | | | | 1.0 |
| | 0.36 | 160 | 418 | 760 | 1050 | 2 | 5% | 22 | 0 |
| | | | | | | | | | 0.5 |
| | | | | | | | | | 1.0 |
| | 0.36 | 160 | 396 | 760 | 1050 | 2 | 10% | 44 | 0 |
| | | | | | | | | | 0.5 |
| | | | | | | | | | 1.0 |

## Specimen preparation:

The concrete was poured in steel moulds of cubes (150) mm size and prisms of (100*100*500) mm size. After the concrete has set in moulds, the specimens were capped with plastic nylon.

After 24 hours of casting, the specimens were demoulded and placed in water for curing. After 28 days of curing the specimens were taken out from water and allowed the surfaces for drying. For all specimens (cubes and prisms) were cast. Then, two levels of temperature (25 and 300)$^0$C were subjected to the specimens in order to find the (compressive and flexural) strengths. The specimens were heated using an electric furnace **Figure (2)** was used to heat the specimens (cubes and prisms). Its temperature capacity is 1200 $^0$C. The furnace temperature was controlled by an electronic thermostat controller. The temperatures were continuously recorded by two thermometers positioned at the mid height side and mid top of the furnace. The furnace was heated gradually, after reaching the selected temperature the specimens were still at that temperature for one hour.

For the cooling regime, the furnace was switched off at the end of the exposure time and the specimens were allowed to cool in the half open furnace for twenty four hours, then after which were removed to cool in air for twenty four hours and then tested.

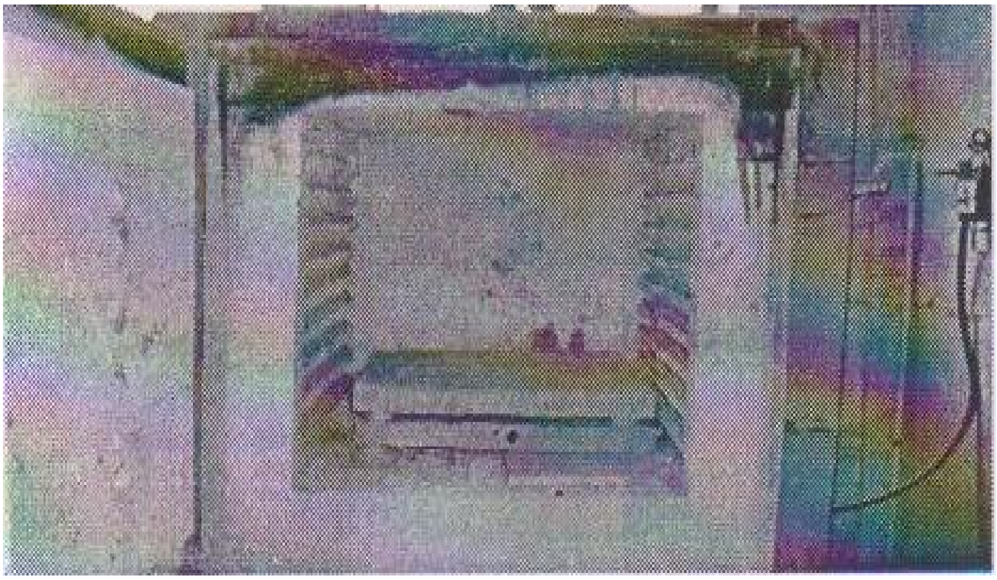

**Fig .(2) The Electric Furnace Used for Heating Specimens.**

## Testing of Flexure Strength for Hardened Concrete:

Flexure strength is calculated using the result obtained from a prism test according to ASTM C78-10 [8] .Test prism measuring (100*100*500)mm are prepared according to ASTM C192-12 [9]. The specimens are tested immediately after they are removed from water. The ELE testing machine **Figure (3)** is used in the test. Flexure strength is obtained by average the result of three specimens since the values obtained are almost very close.

**Fig .(3) Modulus of rupture Test Machine**

In all the specimens, the fracture initiates in the tension surface within the middle third of the span length.

## Testing of Compressive Strength for Hardened Concrete:

Compressive strength is calculated using the result obtained from a cubes test according to BS 1881: Part 108.Test cubes measuring (150*150*150)mm are prepared. The specimens are tested immediately after they are removed from water. The ELE testing machine is used in the test. Compressive strength is obtained by average the result of three specimens since the values obtained are almost very close.

The specimens were demolded and were put in water for 28 days for curing. After the period of curing the stored (cubes) were subjected to a high temperature at an electric furnace to study the effect of elevated temperature (300) ° C and compared with the specimens still at room temperature 25° C.

## Results and Discussion:

### 1- compressive strength:

The results of compressive strength for conventional concrete are shown in Table (10) at 28 days. **Figures (4) to (13)** show the relation between compressive strength and percentage of steel fiber and silica fume.

**Table .(10) Compressive strength results at different temperatures.**

| Mix | Steel Fiber % | Silica Fume % of cement | Compressive Strength at 25°C (MPa) | Compressive Strength at 300°C (MPa) |
|---|---|---|---|---|
| C 40 | 0 | 0 | 42.59 | 34.92 |
| | 0.5 | | 44.22 | 37.14 |
| | 1 | | 46.4 | 39.44 |
| | 0 | 5 | 50.50 | 41.40 |
| | 0.5 | | 53.00 | 42.47 |
| | 1 | | 55.60 | 46.71 |
| | 0 | 10 | 53.72 | 42.96 |
| | 0.5 | | 56.80 | 45.58 |
| | 1 | | 59.90 | 50.33 |

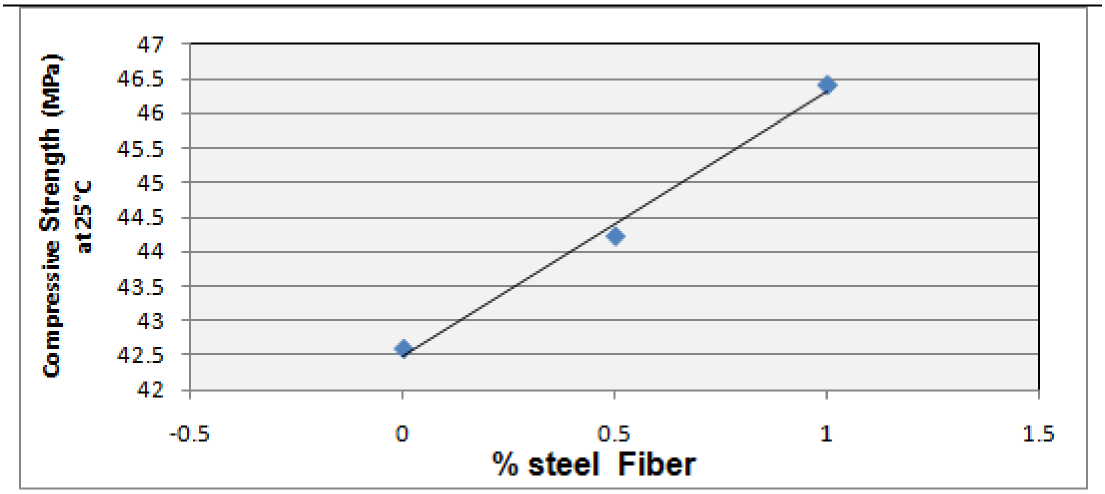

Fig .(4) Compressive strength versus percentage of steel fiber at 25°C

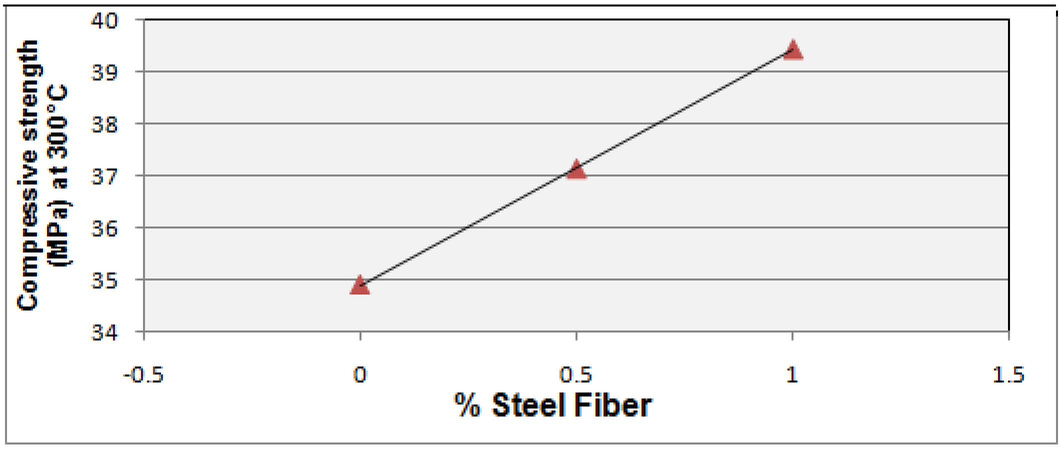

Fig .(5) Compressive strength versus percentage of steel fiber 300°C.

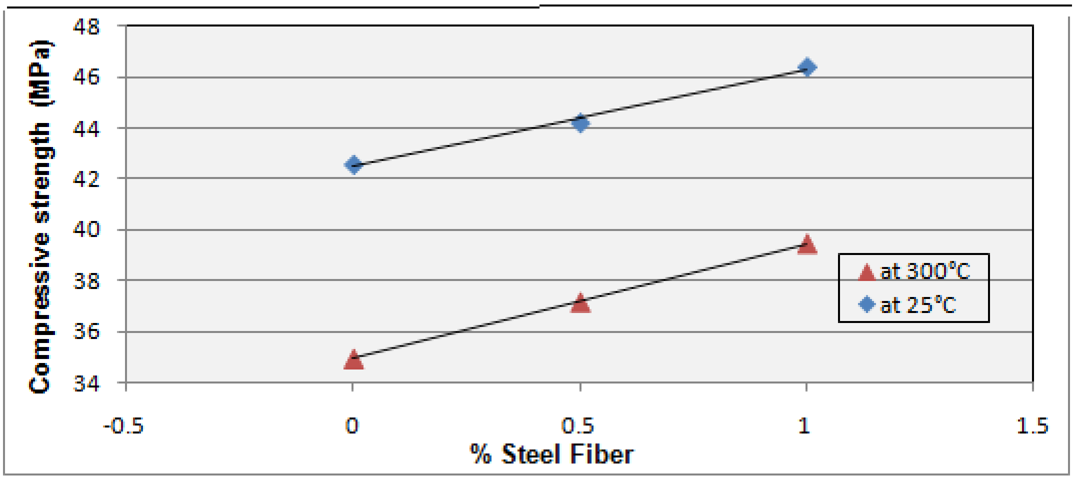

Fig .(6) The relation between compressive strength versus percentage of steel fiber at all level temperature

From the test results illustrated in **Table (10)** and in **Figures (4 to 13)** the following conclusions are obtained:

1. Steel fiber reinforced concrete has low effective in resisting compressive stresses.
2. Silica fume on reinforced concrete is very effective in resisting compressive stresses; the reason for that is the silica fume is very fine powder fill the space between fine aggregate in concrete paste and as a result decreasing the voids in concrete blocks and that lead to increase the compressive strength. So, the silica fume is a very reactive pozzolanic material in concrete. As the Portland cement begins to react chemically, it releases calcium hydroxide. The silica fume reacts with this calcium hydroxide to form additional binder material called calcium silicate hydrate, which is very similar to calcium silicate hydrate formed from the Portland cement. It is largely this additional binder that gives silica-fume concrete its improved hardened properties.
3. The specimens at 25°C have compressive strength greater than the specimens at 300°C (have the same mix proportion), the reason for that is the evaporation of water from concrete over $100^o$ generate a voids in concrete, this make the compressive strength decreases by about (18%, 18.1%, 20%) for (0% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively, the compressive strength decreases by about (16%, 20%, 24%) for (0.5% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively and the compressive strength decreases by about (15%, 15.5%, 16%) for (1% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively. The decrease in compressive strength of concrete is attributed to the break-down of interfacial bond due to incompatible volume changes between cement paste and aggregate during heating and cooling [10].

## 2- Flexure Strength:

The results of flexure strength for conventional concrete are shown in **Table (11)** at 28 days. **Figures (14) to (23)** show the relation between flexure strength and percentage of steel fiber and silica fume.

**Table .(11) Result of Flexure Strength**

| Mix | Steel Fiber % | Silica Fume % of cement | Flexure Strength at 25°C (MPa) | Flexture Strength at 300°C (MPa) |
|---|---|---|---|---|
| **C 40** | **0** | **0** | **6.2** | **3.8** |
| | **0.5** | | **6.5** | **4.0** |
| | **1** | | **6.7** | **4.3** |
| | **0** | **5** | **7.06** | **4.24** |
| | **0.5** | | **7.90** | **4.89** |
| | **1** | | **8.28** | **5.30** |
| | **0** | **10** | **7.40** | **4.44** |
| | **0.5** | | **8.11** | **5.02** |
| | **1** | | **8.74** | **5.50** |

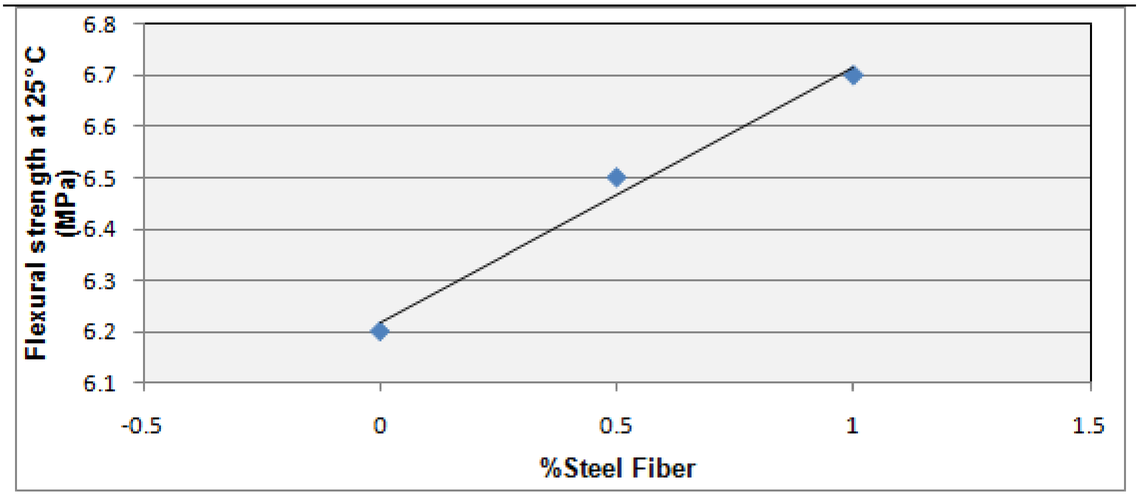

**Fig .(14) The Relation between Flexure Strength and Percentage of Steel Fiber at 25°C**

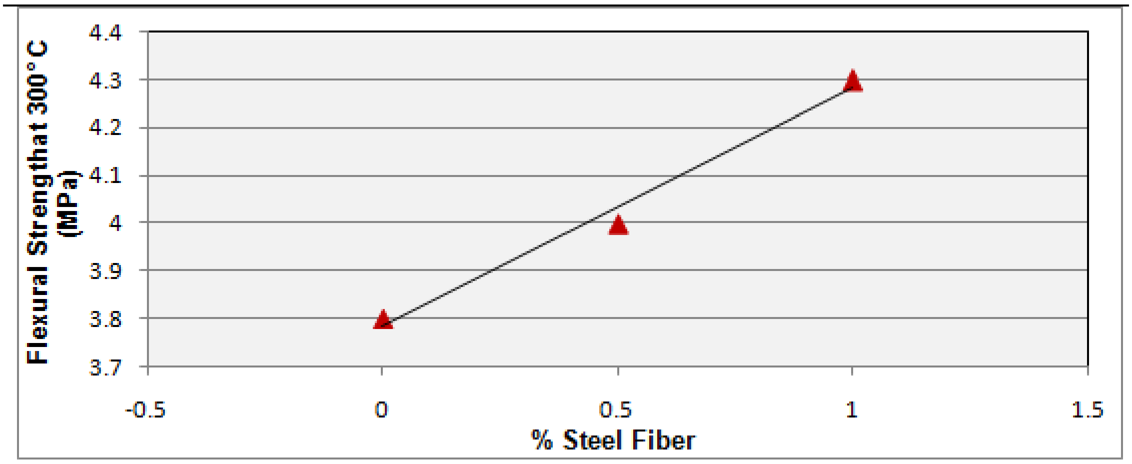

Fig .(15) The Relation between Flexure Strength and Percentage of Steel Fiber at 300°C

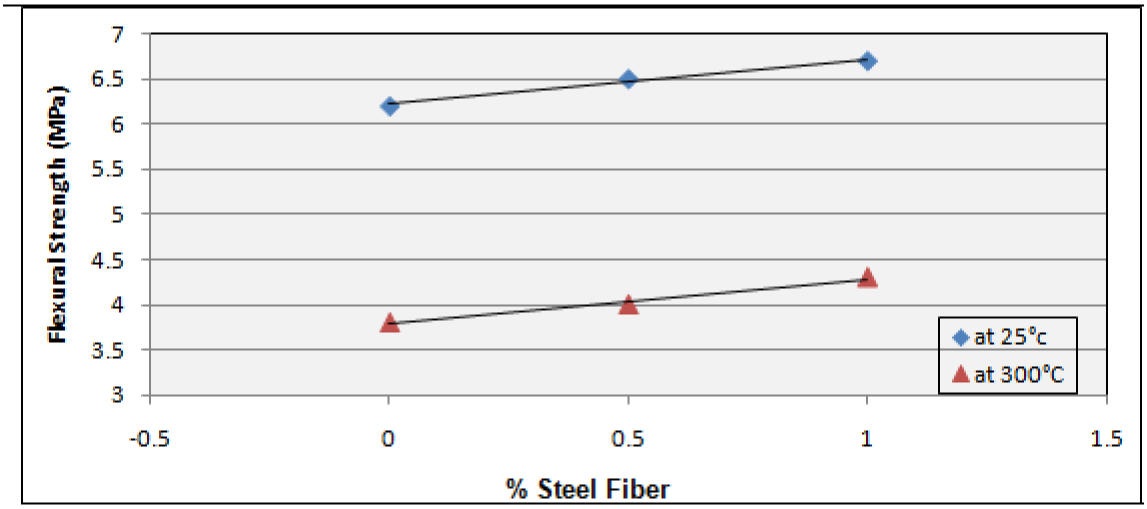

Fig .(16) The Relation between Flexure Strength and Percentage of Steel Fiber at All Level Temperature

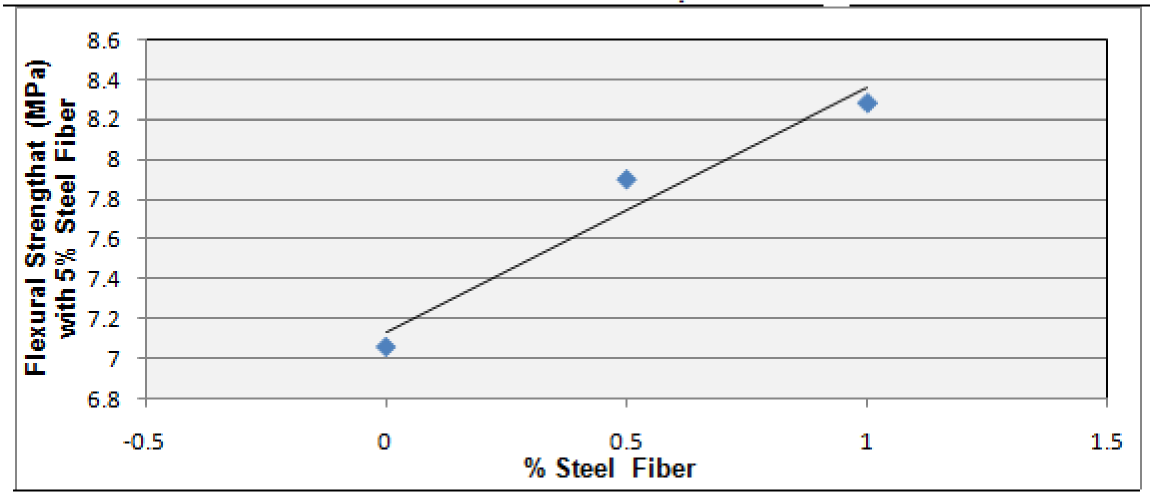

Fig . (17) The Relation between Flexure Strength and Percentage of Steel Fiber with Silica Fume 5% at 25°C

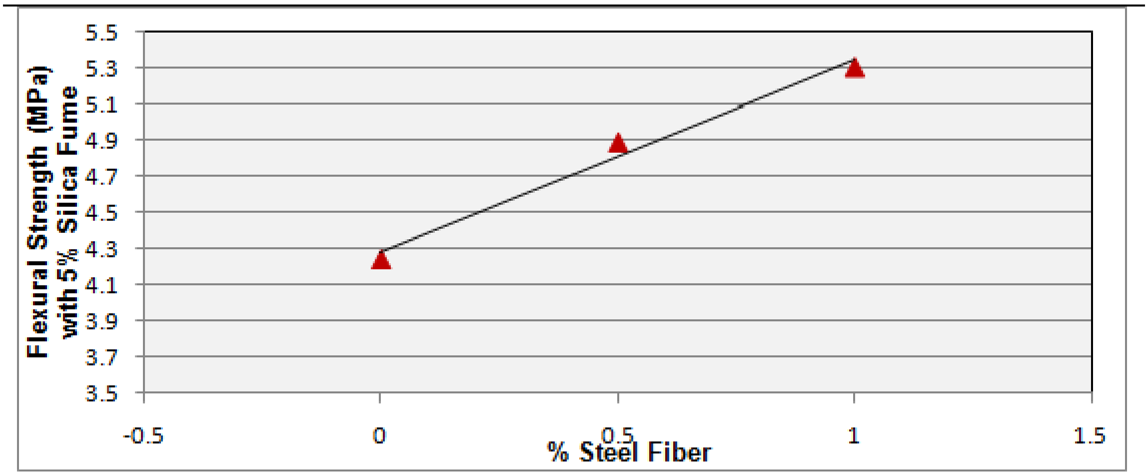

Fig .(18) The Relation between Flexure Strength and Percentage of Steel Fiber with Silica Fume 5% at 300°C

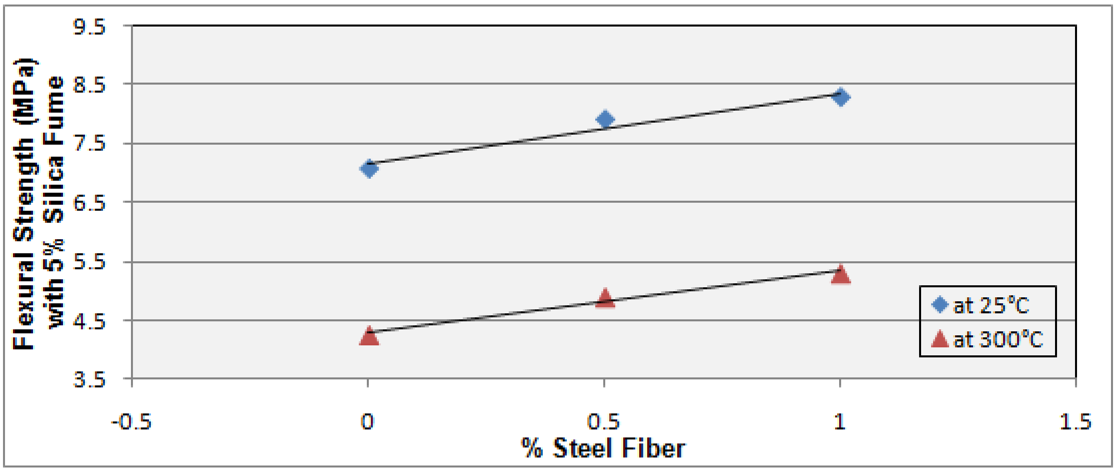

Fig .(19) The Relation between Flexure Strength and Percentage of Steel Fiber with Silica Fume 5% at All Level Temperature

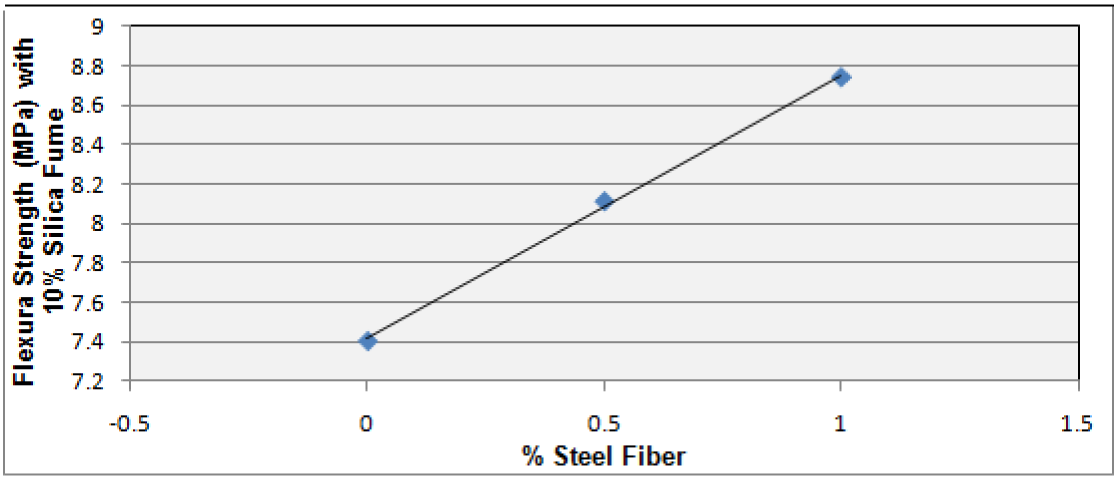

Fig .(20) The Relation between Flexure Strength and Percentage of Steel Fiber with Silica Fume 10% at 25°C

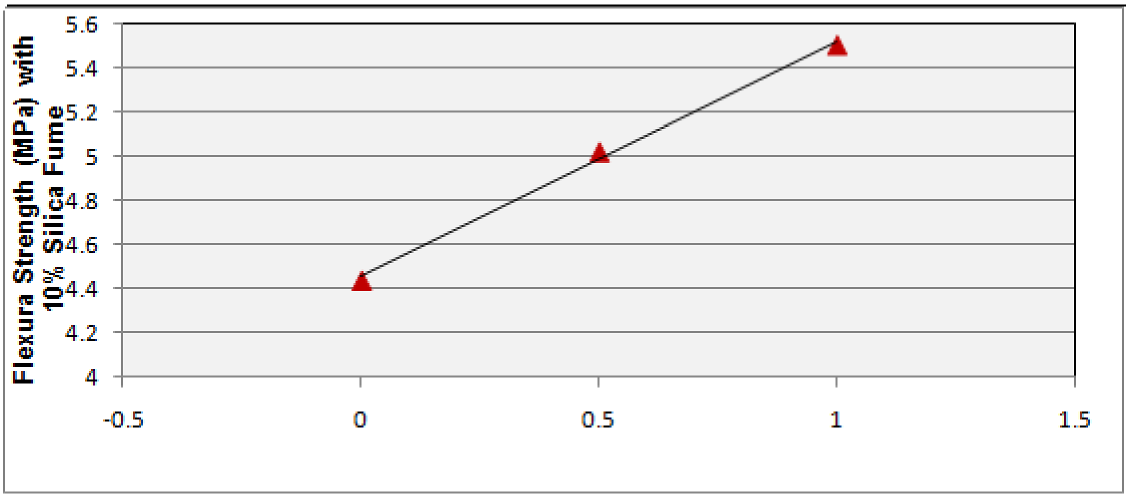

Fig .(21) The Relation between Flexure Strength and Percentage of Steel Fiber with Silica Fume 10% at 300°C

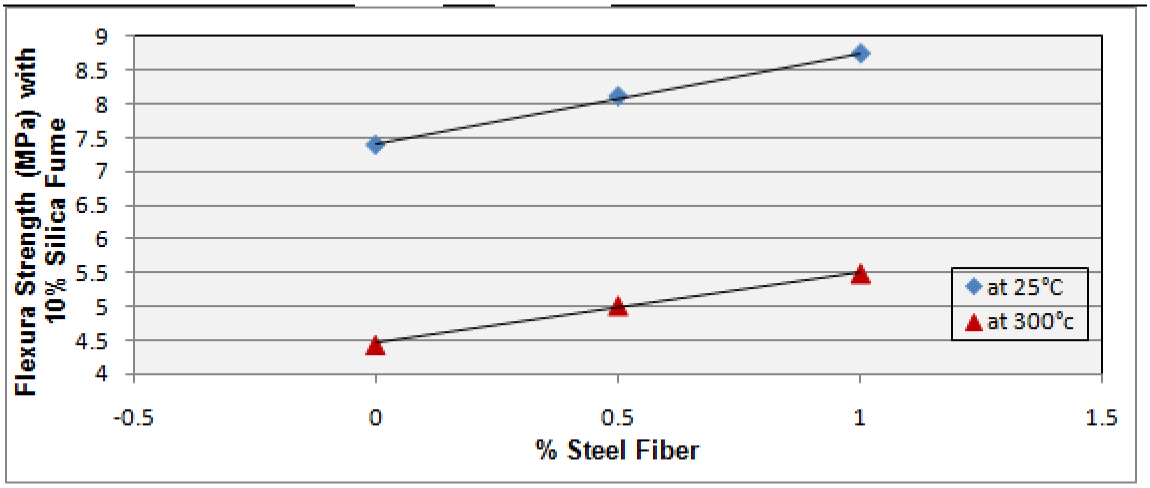

Fig .(22) The Relation between Flexure Strength and Percentage of Steel Fiber with Silica Fume 10% at All Level Temperature

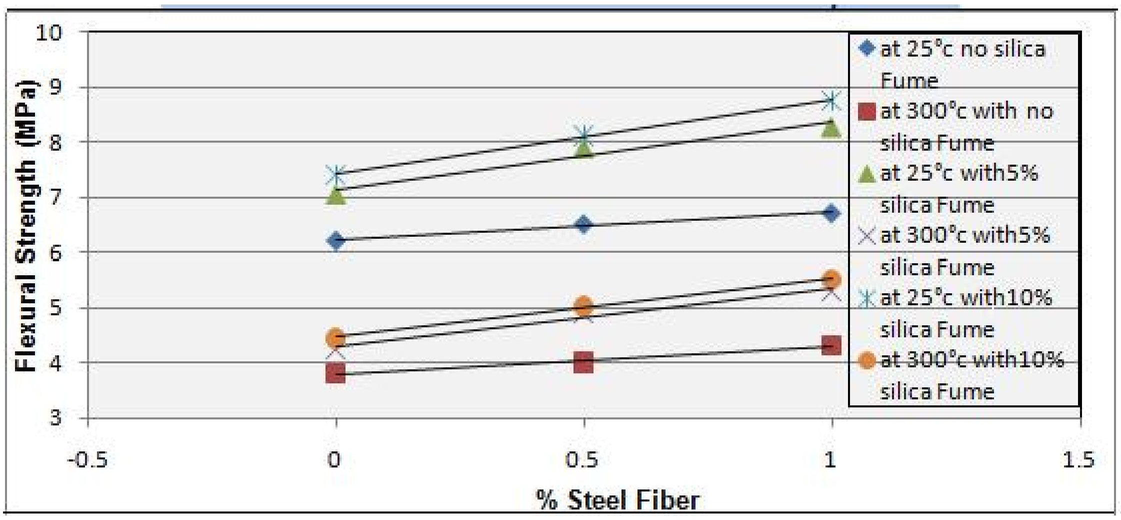

Fig . (23) The Relation between Flexure Strength and Percentage of Steel Fiber with all Percentage Silica Fume at All Level Temperature.

From the test results illustrated in **Table (11)** and in Figures **(14 to 23)** the following conclusions are obtained:

1. Steel fiber reinforced concrete is very effective in resisting flexural tensile stresses as compared to compressive stresses, this is may be due to that the steel fiber work as a bridge connect both sides of crack this leads to delay in cracks extension through concrete section.
2. Silica fume on reinforced concrete is showed little effective in resisting flexural tensile stresses as compared to compressive stresses.
3. The specimens at 25°C have flexural strength greater than the specimens at 300°C (have the same mix proportion), the reason for that is the evaporation of water from concrete over $100^o$ generate a voids in concrete, this make the flexure strength decreases by about (40.3%, 39.9% , 41% ) for (0% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively, the flexure strength decreases by about (38.5%, 38.0% , 38.1% ) for (0.5% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively and the flexure strength decreases by about (35.8%, 36%, 37.07% ) for (1% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively. This is may be due to effect of the high temperature which affects the structure of concrete. So, it can be seen that the addition of steel fibers to concrete would increase the flexural strength of burned concrete at (300°C).

## Conclusions:

The following conclusions can be drawn based on the results of this work:

1- In general, there is a small improvement in compressive strength when adding steel fiber.
2- There is a good improvement in flexural strength when increasing steel fiber.
3- Silica fume on reinforced concrete is very effective in resisting compressive stresses as compared to flexural tensile stresses.
4- The compressive strength decreases by about (18%, 18.1%, 20%) for (0% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively.
5- The compressive strength decreases by about (16%, 20%, 24%) for (0.5% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively.
6- The compressive strength decreases by about (15%, 15.5%, 16%) for (1% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively.
7- The flexure strength decreases by about (40.3%, 39.9% , 41% ) for (0% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively.
8- The flexure strength decreases by about (38.5%, 38.0% , 38.1% ) for (0.5% steel fiber) at 300°C with no silica fume, 5% and 10% silica fume respectively.
9- The flexure strength decreases by about (35.8%, 36%, 37.07% ) for (1% steel fiber) at 300°C at 300°C with no silica fume, 5% and 10% silica fume respectively.

Note: The results of compressive strength and flexural strength are compared with cubes and prisms respectively tested at room temperature (25 °C).

## References:

1. **R.M.Damgir and Y.M.Ghugal, " Compressive Strength for FRC Member using Silica Fume", Shaheen Khatoon et al. / International Journal of Engineering Science and Technology (IJEST), Vol. 3, No. 1, Jan 2011.**
2. **A.A.Elasyed, "Influence of silica fume and steel fiber on cement ", Journal of Jordan Vol. 5, No. 2, 2011.**
3. **Falah A., "The Mechanical Properties Of Silica Fume" Journal of Marine Science and Technology, 2007, Vol. 4, No. 1.**
4. **L. wei and H.Ran, "Effect Of Steel Fiber On The Mechanical Properties Of Cement-Based Composites Containing Silica Fume" Journal of Marine Science and Technology, 2008, Vol. 16, No. 3, pp. 214-221.**
5. **R.J. Craig, “Structural applications of Reinforced Steel Fibrous Concrete”. Concrete Int. Design and Construction 1984.**
6. **المواصفات العراقية رقم 5، "السمنت البورتلاندي" ، الجهاز المركزي للتقييس والسيطرة النوعية، بغداد، 1984، ص 8**
7. **المواصفات العراقية رقم45، " ركام المصادر الطبيعية المستعملة في الخرسانة والبناء" الجهاز المركزي للتقييس والسيطرة، بغداد، 1984.**
8. **ASTM C78-10, "Test Method for Flexure Strength of Concrete ".**
9. **ASTM C192-12, "Practice for Making and Curing Concrete Test Specimens in Laboratory".**
10. **ضياء نوري ناصر، "تأثير الحرارة على بعض خواص الخرسانة "، رسالة مقدمة إلى قسم هندسة البناء والإنشاءات في الجامعة التكنولوجية لنيل درجة الماجستير، العراق، بغداد، 1983، عدد الصفحات 116**