EFFECT OF SHAPE AND TYPE OF STEEL FIBRE ON SOME MECHANICAL PROPERTIES OF REINFORCED CONCRETE

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Abstract

This investigation was carried out to study the effects of fibre reinforced concrete on compressive strength, tensile strength, shrinkage, tensile strain capacity, crack width, and cracking time of concrete.

Laboratory tests were made on end-restrained plain and fibre reinforced concrete beams and by using specimens cubs (150mm) and cylinders (100*200mm). Two types of fibres were used and their volume fraction ranged from 0.25% to 2%.

Based on the results of this work, it was found that the compressive strength decreases with increasing fibre content for both types of fibre, but the maximum compressive strength and splitting tensile strength at 1.5% crimped fibre content.

The test results showed that fibre addition decreases shrinkage of concrete significantly. It also reduces crack width. It was also found that tensile strain capacity decreases and cracking time increases with fibre addition. The magnitude of the charge in properties, however, depends on the type of fibre used.

1. Introduction

Cracking of concrete is perhaps its major disadvantages which results mainly from its low tensile strength and low tensile strain capacity, where concrete is considered as a brittle material and locks ductility.

In general, concrete cracks when there are tensile stresses exceeding in magnitude its tensile strength.

A voiding cracks or controlling their widths is therefore an important engineering problem. This problem is especially important in countries having hot weather, because in such countries, the temperature is usually high and the relative humidity is relatively low. Restrained concrete movement under such conditions usually leads to cracking; such cracking is usually controlled by steel reinforcement.

In the present work, an attempt is made to study the effect of type of fibres and fibre content on the some mechanical properties of concrete, such as compressive strength, splitting tensile strength and restrained shrinkage cracking of concrete.

2. Literature Review

2.1 Effect of Fibre Content on Shrinkage

Balaguru and Ramakrishna (1) showed that the shrinkage strain is slightly less for fibre reinforced concrete and measurable shrinkage stops at an earlier age for fibre reinforced concrete compared with plain concrete.

Al Tayyib *et al*(2) proved that the inclusion of 0.2% polypropylene fibres eliminates plastic shrinkage cracking in slabs subjected to temperature as high as 40-46 °c.

Mangat *et al* (3) used melt extract, plain, crimped and hooked steel fibres. They showed that fibres restrain shrinkage of the various cement matrices to a significant extent and that the restraint with increasing fibre volume resulting in reduction in shrinkage of up to 40%. They showed also that the crimped fibres are more efficient in providing shrinkage restraint.

Sorcushian *et al* (4) studied the effect of polypropylene fibres on the plastic shrinkage. They found that the polypropylene fibres reduce the total plastic shrinkage, crack area and maximum crack width at 0.1% fibre volume fraction.

Kronlof *et al* (5) used 1.0% polypropylene fibres. They found that the use of fibres reduces free shrinkage by about 30% compared to mixes without fibres.

2.2 Shrinkage Induced Cracking

Shrinkage may cause cracking of concrete. If the shrinkage takes place without any restraint, the concrete would not crack.

However, in practice the concrete is always under some degree of restraint either externally. According to **Al-Rawi (6)** the combination of shrinkage and restraint develops tensile stresses. When the induced strain exceeds the tensile strain capacity of the concrete, cracking takes place. Alternatively, when the developed stress the tensile strength of concrete, cracking occurs as shown in Figure [2-1].

The magnitude of tensile stress developed during drying of the concrete is influenced by a combination of factors such as:-

I – the amount of shrinkage,

II – the degree of restraint,

III – the modulus of elasticity of the concrete, and

IV – the creep or relaxation of the concrete.

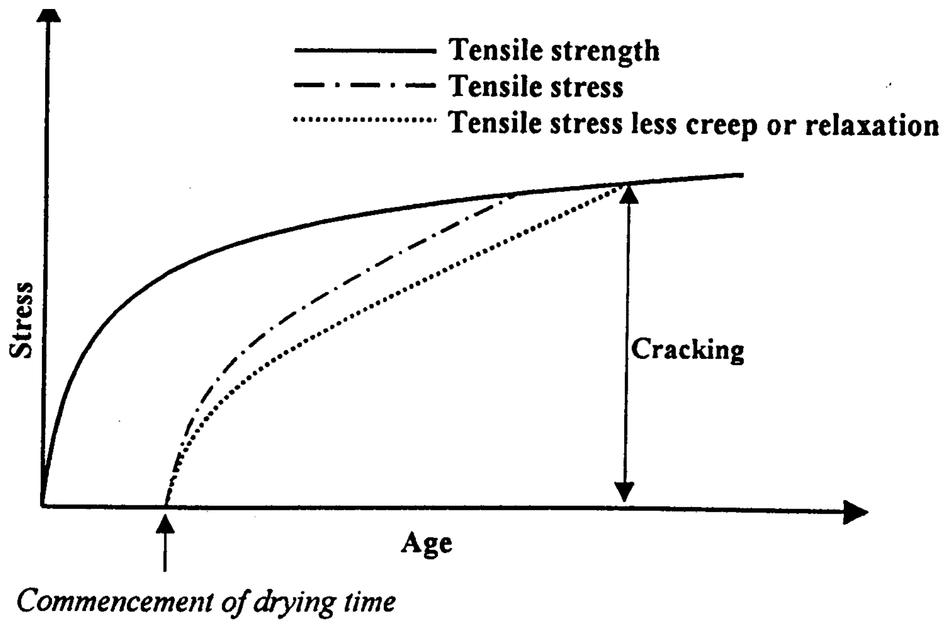


Figure (2-1): Sketch of crack development (stress wise)

Thus, the amount of shrinkage is only one factor governing cracking for perverting of shrinkage cracking, low modulus of elasticity and high creep characteristics of the concrete are desirable since they reduce the magnitude of tensile stresses (7).

Al-Rawi and Kheder stated that the need to control crack spacing and width in reinforced concrete structures arises from aesthetic reasons, water tightness requirements, Concrete durability, structural safety, and preservation of steel reinforcement considerations (8).

2.3 Effect of Fibres on Restrained Shrinkage Cracking

Swamy and Stavrides (9) used a ring for restraining shrinkage to demonstrate the ability of polypropylene, glass and steel fibres to control restrained shrinkage cracking. They stated that the fibre reinforcement delays the formation of the first crack, prevents sudden failure observed with unreinforced matrices, enables the composite to suffer multiple cracking without failure and reduces crack widths substantially.

Ong *et al*(10) showed that a higher volume fraction of steel fibres is more effective in controlling cracks due to simulated restrained shrinkage, and with 1.0% volume fraction of steel fibres the maximum crack width decreased by ten times and the first crack strain doubles compared with unreinforced specimens.

Krstulovic *et al* (11) presented cement based composite that, in their opinion, promise to provide a long term solution to bridge deck problems. These include: high-performance steel fibre reinforced concrete and improved conventional steel fibre reinforced concrete. They reported that on a bridge deck in (U.S.Rt.30.ohio) with 0.8% steel fibre concrete only some micro cracks appeared. On a highway (8 Mile Rd. Detroit) 0.9% of wirand steel fibres and 1.5% of Fibercon steel fibers were used. There are some early cracks, but Fibercon steel fibers preformed much better than Wirand steel fibres. They also reported on many other projects in U.S. were the steel fibre concrete used for repair work with different fibre volume fractions. In most cases cracking was minimum or a bent.

2.*4 Cracking of End-Restrained and Base-Restrained Reinforced Concrete Members*

Since the restraining edges exist only at the member ends, the restraint in such members will be uniform; accordingly, a uniform state of tensile strain will develop in the member as it shrinks or contracts. Cracking of the member will therefore begin to propagate at the weakest section existing at any position within the member length(8).

In fact crack location depends mainly on the position pf the weakest concrete section. As discussed previously, for a fully developed crack pattern, the spacing between cracks must be between $\mathbf{S}_{min}$ (bond slip distance) and $\mathbf{S}_{max}$ (twice the bond slip distance). As can be seen from figure (2-2).

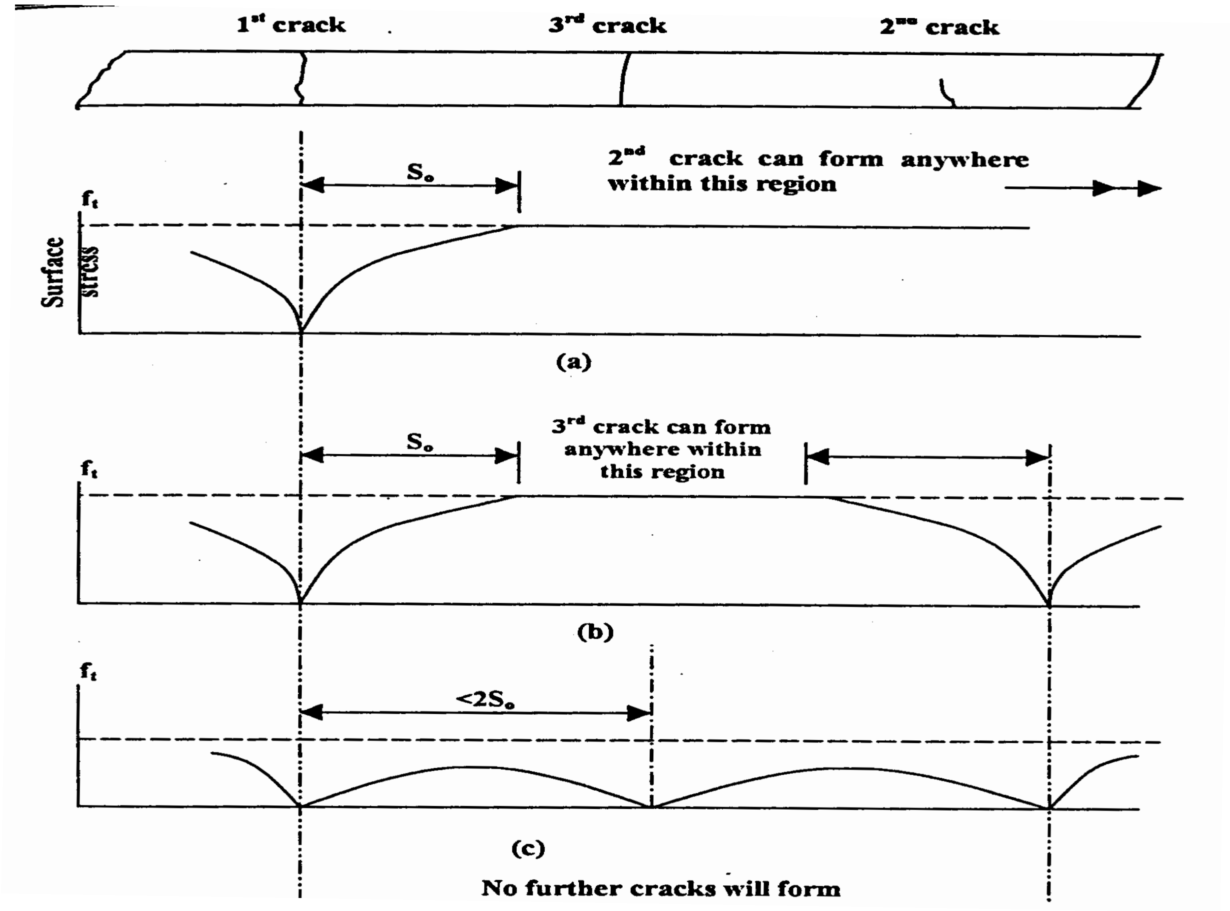


Figure (2-1): Concrete stress condition during the development of cracking.
(D_b=) $\mathbf{S_{min}}$ < S < Smax (=2D_b)
Where (D_b) is the bond slip distance.

Al-Rawi (10, 11) used I-shaped moulds having a channel section to study shrinkage crack spacing and crack width. He used concrete reinforced with deformed bars and welded wire mesh. He found that using the deformed bar reinforcement can control both the minimum crack spacing and the maximum crack with. On the other hand, the use of the welded wire mesh may lead to erratic crack spacing. He developed formulas for both minimum and maximum crack spacing and for maximum crack width in there members.

2.5 Cracking Age

It is the time required for the shrinkage induced strains to build up and exceed the tensile strain capacity of concrete. The age of first crack and the cracking sequence is dependent on the same factors that influence the cracking tendency of concrete (i.e. degree of restraint, shrinkage, creep, tensile, strain capacity … etc). Thus, cracking age, as stated by **Al-Rawi (12)** could be used as an index to asses the possibility of cracking of various.

Al-Rawi (13) reported that the cracking time depends on both shrinkage and tensile strain capacity. It increases with decreases in W/C ratio (mix proportion being unchanged), and with increase in normal curing time and amount of crushed coarse aggregate.

3. Experimental Work

3.1 Program of Works

In the present work, the program of the work and the shrinkage-cracking models was based on the models devised by **Al-Rawi [12].**

This research was designed to study the effect of steel fibres on shrinkage cracking of end-restrained concrete members. 0%, 0.25%, 0.5%, 1.0%, 1.5% and 2.0% steel fibre content were used to determine shrinkage cracking behavior of concrete. For each shrinkage test, a set of six cubes specimens (150*150*150) mm and cylinders specimens (100*200) mm were cured in the laboratory for compressive strength and splitting tensile strength test at 7 and 28 days.

3.2.1 Molds

The molds were used in the present study of 2.2 meter -shape steel mold as shown in figure (3-1) and plate (3-1), were used to study shrinkage and shrinkage cracking of end-restrained plain and fibre reinforced concrete.

The mold's was greased, covered with tow layers polyethylene sheet and oiled to minimize base friction. The ends of the mold offer end-restraint to the web, so that transverse cracks a cross the web would form as a result of stresses induced when the concrete in the web shrinks.

3.2.2 Materials and Mixes

3.2.2.1 Cement

The cement used in this study was Ordinary Portland cement (O.P.C.) produced at Kufa factory. This cement compiled with the Iraq specification No.5 / 1984 [14].

3.2.2.2 Fine Aggregate:

Al-Khaider well-graded natural Silica sand was used. The results of physical and chemical properties of the sand are listed in table [A-1]. Its grading conformed to the Iraqi specification No.45 / 1984[15], zone (3).

3.2.2.3. Coarse Aggregate

The gravel used was brought Al-Nibaii area with a maximum size of 19 mm. The grading and other properties of this type of aggregate were tested and shown in Table [A-2].

Plate (3-1): - Shaped beams used for measuring the first day movement and elastic tensile strain capacity.

3.2.2.4. Water

Tap water was used throughout this work for both mixing and curing of concrete.

3.2.2.5. Fibres

Tow type of steel fibres were used.

1- Straight end Hooked Steel Fibres

They were made of hard-drawn steel wires having a mean section of 0.3*0.4 mm and length of 40 mm.

2- Crimped Steel Fibres

The crimped fibre, each fibre has three waves along its length specific gravity of the material is about (8.0). The cross section is circular with 0.3 mm diameter, uncrimped length 30 mm, and 25 mm crimped length giving an aspect ratio L/D of 80.

3.2.2.6. Mix Design and Proportions:-

The concrete mix was designed according to British mix design method B.S. 5328: part 2: 1991[16].

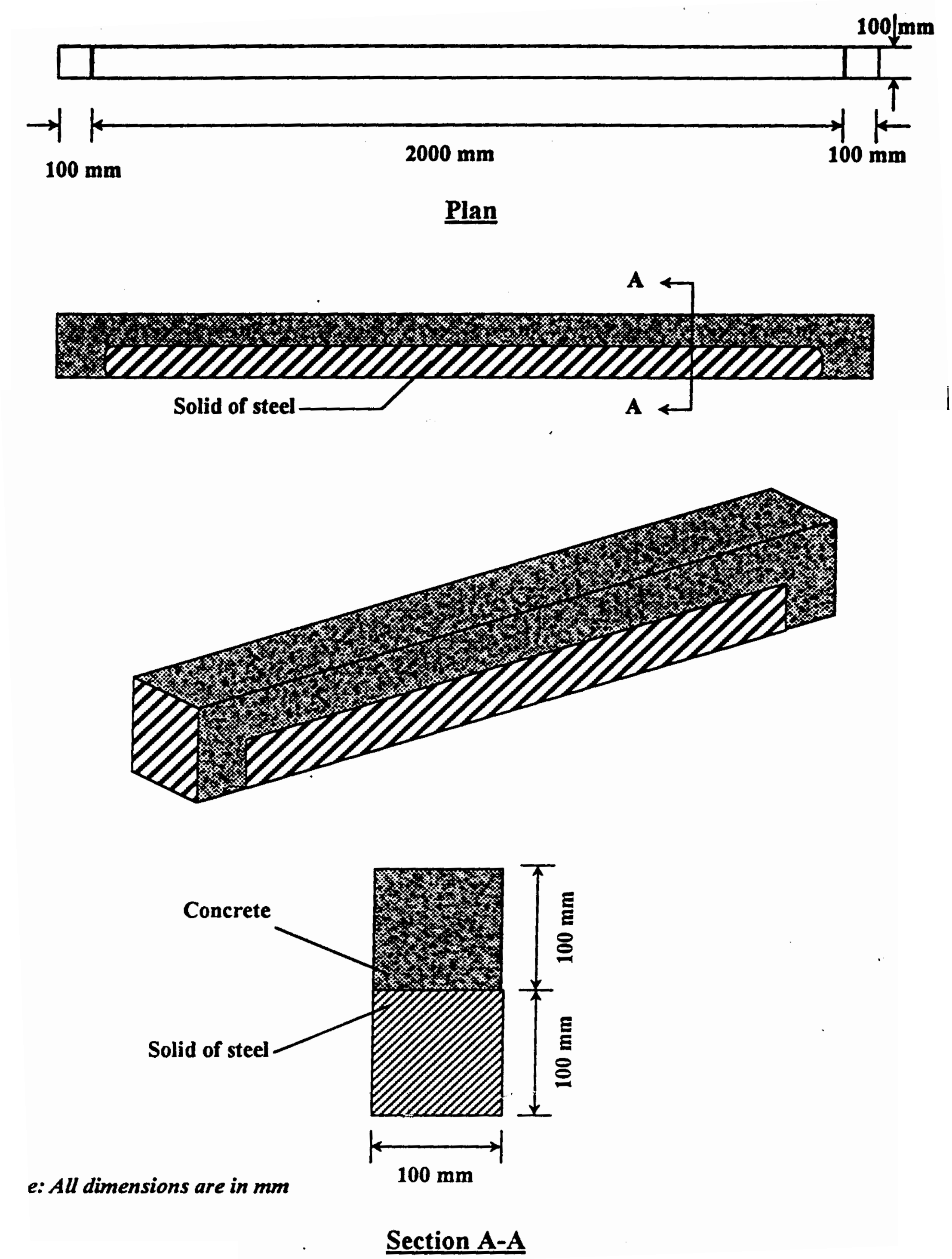


Figure (3-1): Schematic diagram of ⊓ -shape.

The proportions of the concrete mix are summarized in Table [3-3].

Table [3-3]: Mix Proportion

		Weight proportion	Mix proportion Kg/m³			
Slump Mm	W/C ratio	Cement :sand : gravel	Water	Cement	Sand	Gravel
60	0.45	1.0 : 1.2 : 2.7	195	435	525	1215

3.2.2.7. Concrete Mixing and Casting

Concrete was mixed in a drum by hand to avoid balling of fibres, especially with high volume fraction. The sand and gravel were mixed first, then the cement and water were added, and mixing continued to obtain a homogenous mix. The fibres were then added gradually while mixing. The concrete was cast in the already prepared molds in the special laboratory room and vibrated by portable electrical vibrator.

3.2.2.8. Curing and Exposure

To prevent plastic shrinkage cracking due to rapid evaporation from the upper surface of the beams. Wetted Hessian sheets and polythene sheets were used to cover the upper surface of the beams after 30-40 minutes from the casting. The cube and cylinder specimens were cured in water in the laboratory for 7 and 28 days compressive strength tests.

3.2.2.9. Method of Measurement

The crack width was measured by a crack microscope. Measurements were started from the first day after casting and repeated daily until the readings indicated that cracking and movement had reached stable conditions. The free shrinkage was measured in the same way by measuring the widening of the artificial crack in the middle of the beam daily, until the readings indicated that cracking and movement had reached stable conditions. The measured devices were used in this research as shown in plate (3-2)

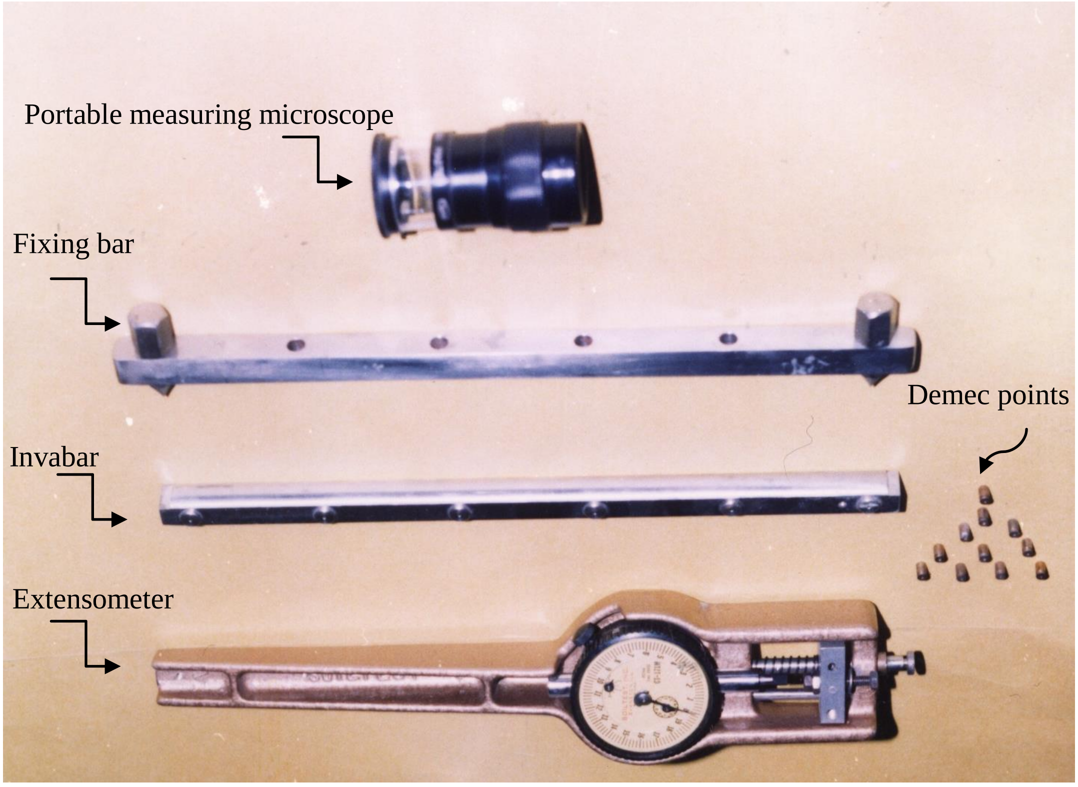


Plate (3-2): Measurement devices.

4- Experimental Results and Discussion

4.1. Introduction

Experimental results are presented in this chapter showing the effect of restrained in some mechanical properties of concrete by using the model described in the chapter three.

4.2. Compressive strength

Table (4-1) shows the compressive strength of plain and fibre reinforced concrete, while figure (4-1) show the relation between compressive strength and age.

Table (4-1): Test values of compressive strength of plain and fibre reinforced concrete.

Fiber content	Compressive strength (MPa) at 7 days	Compressive strength (MPa) at 28 days	Compressive strength (MPa) at 60days
Plain concrete	19.80	33.50	47
0.25% *C_f fibres	18.50	30.60	44.5
0.50% C_f fibres	17.75	29.85	42.8
1.00% C_f fibres	21.00	29.00	41
1.50% C_f fibres	16.00	34.20	49.7
2.00% C_f fibres	15.20	28.05	38.4
1.00% *S_f fibres	16.25	26.85	36.5
2.00% S_f fibres	16.90	27.00	33.8

***Cf Crimped fibre**
***Sf Straight fibre**

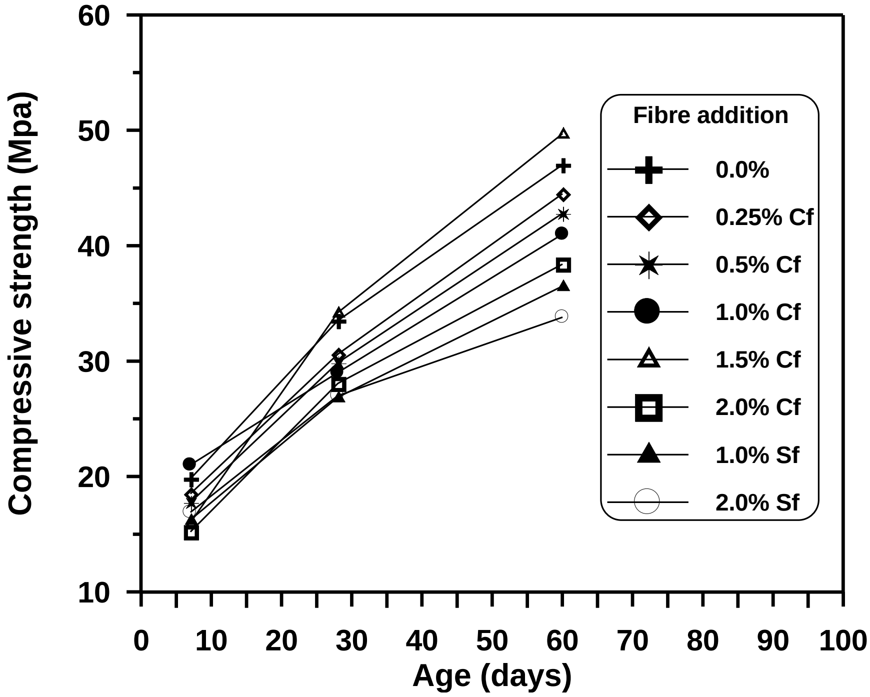


Figure (4-1): Relationship between compressive strength of plain and fibre reinforced concrete with age

It can be seem from the above figure that, in general for the both types of fibres, with increasing fibre content, the compressive strength decreases. These results agreed with that obtained by **Al-Badry (17)** and **Purkiss (18)**.

4.3 Splitting Tensile Strength

The values of splitting tensile strength of the specimens considered in the present investigation are abstracted in table (4-2). The relation between the splitting tensile strength and age is shown in figure (4-2). It is clear from the test results that the splitting tensile strength is more sensitive to the volume fraction and type of fibre. It can be also seen from figure (4-2) that the splitting tensile strength decreases with increasing fibre content, similar results it was found by **Purkiss (18)**.

Table (4-2): Test values of splitting tensile strength of plain and fibre reinforced concrete.

Fiber content	Splitting strength (MPa) at 7 days	Splitting strength (MPa) at 28 days	Splitting strength (MPa) at 60days
Plain concrete	2.23	3.85	4.2
0.25% C_f fibres	2.00	2.60	4.12
0.50% C_f fibres	1.92	2.45	2.70
1.00% C_f fibres	2.18	3.85	4.00
1.50% C_f fibres	1.80	2.20	2.43
2.00% C_f fibres	1.65	2.00	2.3
1.00% S_f fibres	1.60	2.00	2.20
2.00% S_f fibres	1.42	1.75	1.98

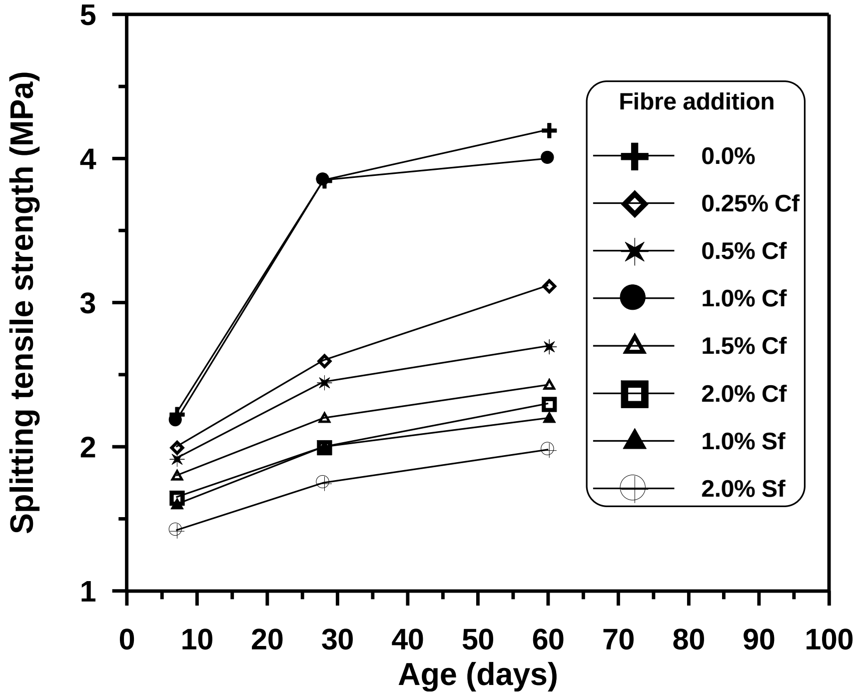


Figure (4-2): Relationship between splitting tensile strength of plain reinforced concrete with age and fibre

4.4 Cracking Age

The cracking age can be used as an index for the vulnerability to cracking (19). Figure (4-3) shows that addition of both types of fibre increased the cracking time from 4 days for plain concrete up to 13 days for 2% addition of crimped fibres and to more than 60 days for 2.0% straight hooked end fibres. In the latter case no cracking occurred even through shrinkage terminated at the age of 18 days.

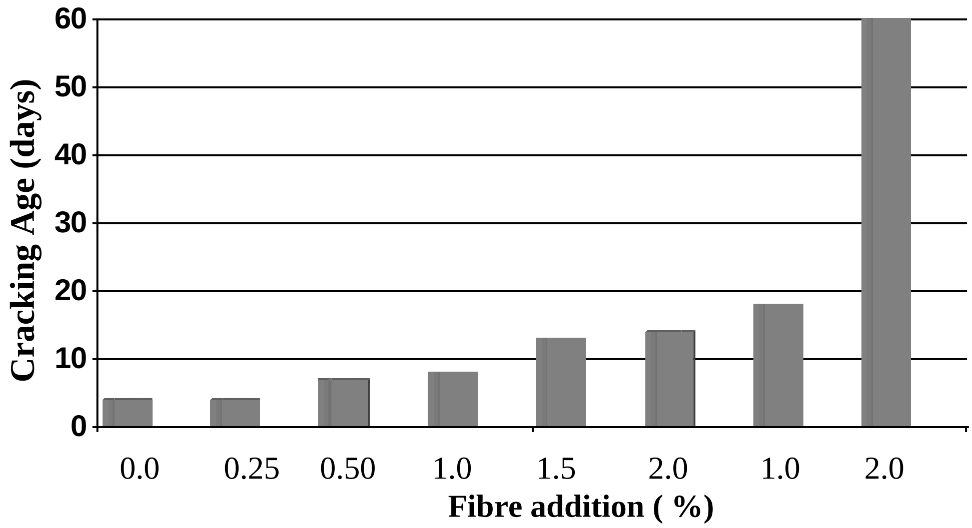
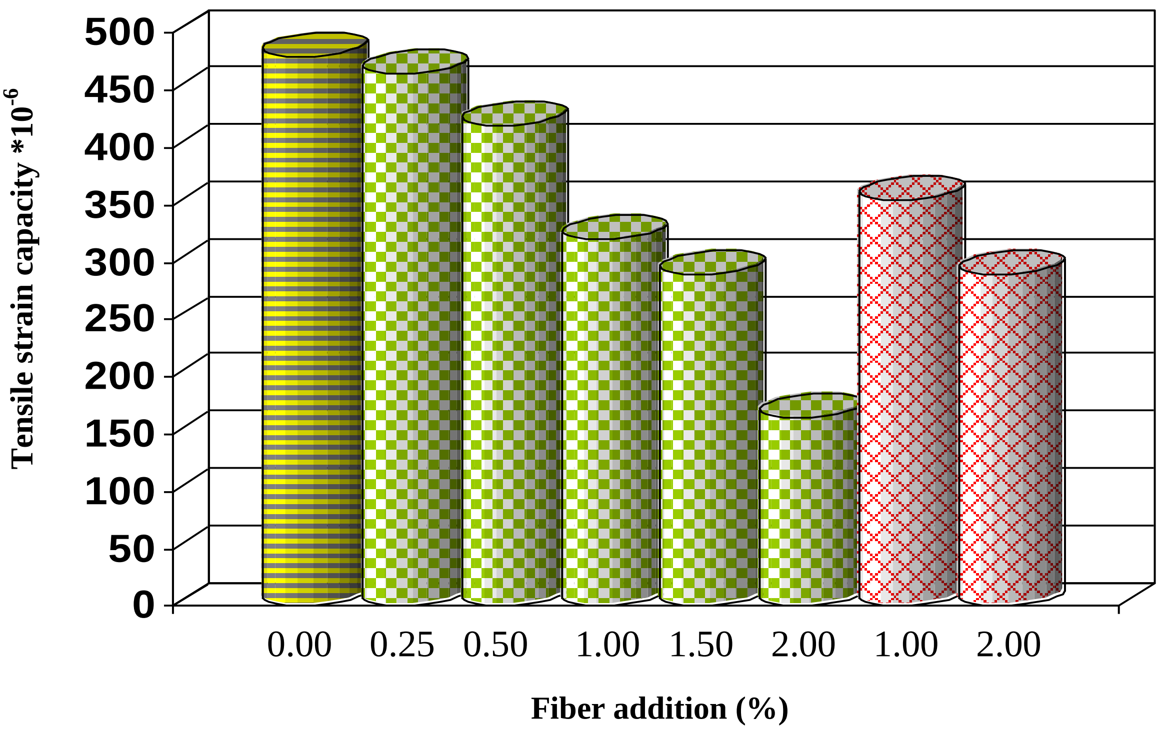


Figure (4-3): Relationship between fiber addition and cracking age.

4.5 Elastic Tensile Strain Capacity

Elastic tensile strain capacity of concrete was obtained directly by measuring the immediate movement after cracking of plain concrete of channel - shaped beams. It was also measured indirectly by determination of tensile strength and dynamic modules of elasticity. The elastic tensile strain capacity is taken as the tensile strength divided by the dynamic modulus of elasticity. Figure (4-4) shows that tensile strain capacity of concrete with and without fibre is considerable greater than that reported in previous literature, but it is in line with these obtained in some recent literature (6). The same figure shows that the tensile strain capacity decreased with increased fibre addition. In the case of crimped fibres the lowest tensile strain capacity ($155 *10^{-6}$) was obtained with 2% fibre addition. In the case of straight hooked end fibres no cracking took place with 2% fibre addition i.e. the tensile strain capacity was more than ($270 *10^{-6}$), which is the ultimate free shrinkage measured in this case. Similar results were obtained by **Al-Badry (17)**.



Figure(4-4): Relation between tensile strain capacity of reinforced concrete and fibre addition

4.6 Free Shrinkage

Tables (4-3), (4-5) and (4-6) give the results of free shrinkage of plain and fibre reinforced concrete. Figure (4-5) shows that free shrinkage of plain concrete is relatively high especially at early ages. The maximum free shrinkage strain obtained was $850*10^{-6}$, which is to be expected under the present exposure conditions the exposure to sever conditions was indented to resemble filed condition in summer in Iraq. These conditions promote shrinkage cracking of concrete.

Figure (4-5) also shows that the addition of crimped fibres in all cases decreased the shrinkage of concrete. The magnitude of decrease depends on the fibre content added. With increased fibre content the shrinkage decreases. Up to 52% decrease was obtained with crimped fibres. The age at which shrinkage terminates in case if crimped fibre addition increased compared with plain concrete.

Figure (4-6) shows that, with addition of straight fibres, shrinkage terminates at the age of 26 days for 1.5% fibre addition and at 16 days for 2% fibre addition. Hence, in this case the addition of fibre decreased the age at which shrinkage terminates compared with plain concrete.

Figure (4-7) shows that the ultimate shrinkage of concrete with 1.5% fibre addition is about the same for both straight fibres and crimped fibres. The magnitude of the ultimate shrinkage in this case is less than half that of plain concrete.

Figure (4-8) shows that the ultimate shrinkage of concrete with 2% crimped fibre is greater than that of straight fibre, with the same fibre content. However, the age of termination of shrinkage of concrete with 2.0% crimped fibre addition (42 days) is greater than that of plain concrete (26 days). It is also greater than that of concrete with 2% straight fibres (16 days).

Table (4-3): Free shrinkage strain for plain and crimped fibre reinforced concrete beams

Age (days)	Shrinkage Strain in millionths					
	Fibre Addition (%)					
	0.00	0.25	0.50	1.00	1.50	2.00
1	220	135	125	100	70	35
3	385	275	270	135	135	90
7	590	410	400	290	205	155
15	810	535	515	365	250	220
20	840	625	620	420	270	255
30	865	660	655	485	295	275
45	875	690	680	530	300	295
60	880	705	695	570	320	310
70	880	705	700	570	320	310

Table (4-4): Free shrinkage strain for plain and 1.5% straight and crimped fibre of reinforced concrete beams.

Age (days)	Shrinkage Strain in millionths		
	Fibre Addition (%)		
	0.00	1.50 C_f	1.5 S_f
1	220	70	40
3	385	135	90
7	590	205	145
15	810	250	230
20	840	270	255
30	865	295	265
45	875	310	280
60	880	320	290
70	880	320	290

Table (4-5): Free shrinkage strain for plain and 2.0% crimped and straight fibre of reinforced concrete beams.

Age (days)	Shrinkage Strain in millionths		
	Fibre Addition (%)		
	0.00	2.0 C_f	2.0 S_f
1	220	35	15
3	385	90	35
7	590	155	90
15	810	220	175
20	840	255	195
30	865	275	200
45	875	295	205
60	885	310	205
70	885	310	205

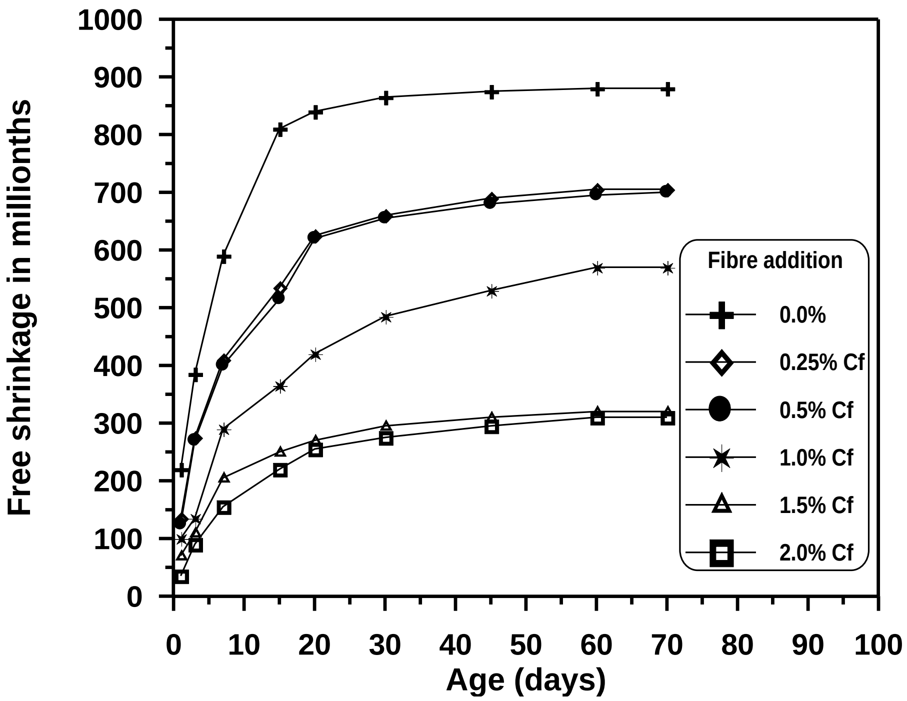


Figure (4-5): Relationship between free shrinkage strain of plain and straight fibre reinforced concrete beams with age

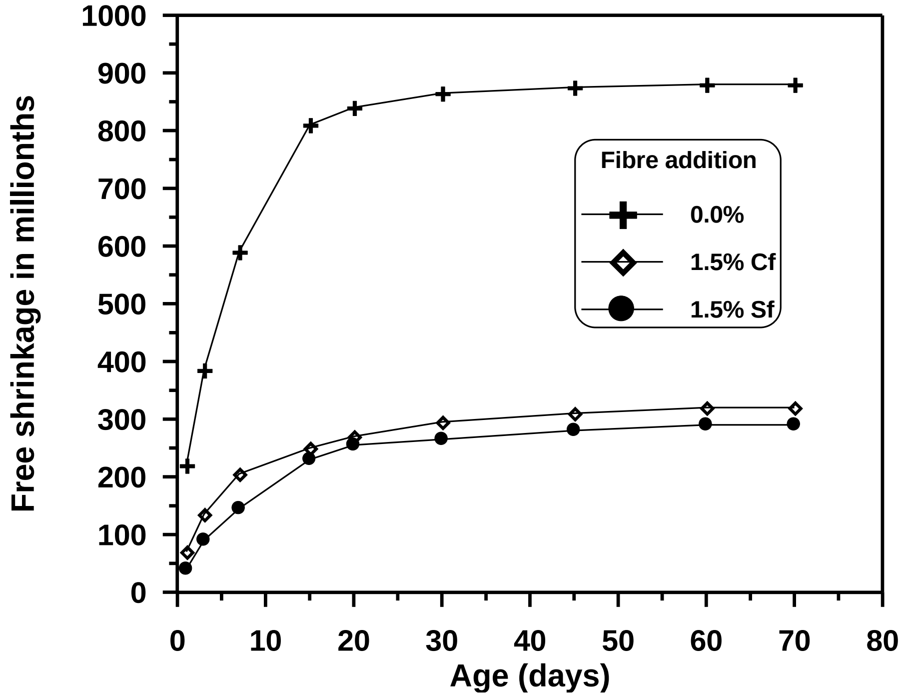


Figure (4-6): Relationship between free shrinkage strain of plain and 1.5% Straight and crimped fibre reinforced concrete beams with age

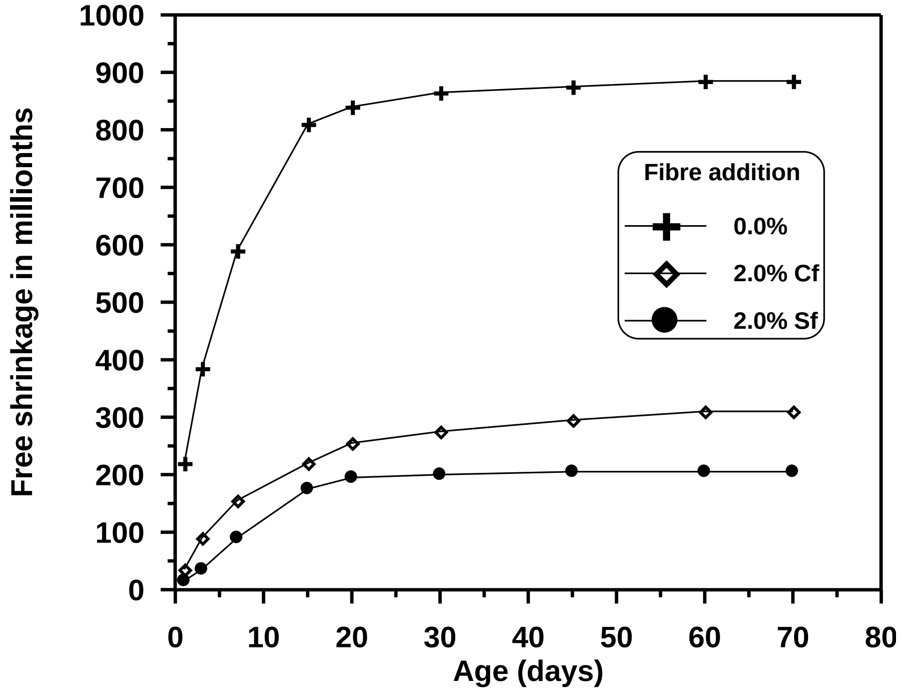


Figure (4-7): Relationship between free shrinkage strain of plain and 2% crimped and straight fibre reinforced concrete beams with age

4.7 Restrained Shrinkage

The effect of fibre addition on the restrained shrinkage of reinforced concrete beams is summarized in table (4-6), (4-7), (4-8) and (4-9). Figure (4-7) shows that with increased crimped fibre addition the restrained shrinkage crack width decreases. It can also be seem with 2% fibre addition, the crack width decreases to about 42% of that of plain concrete.

It can be seen from figure (4-8) that the crack width in the case of concrete with 1.5% straight fibre addition is about 22% that of plain concrete. Figure (4-8) also shows that with 2% addition of this fibre, no cracking took place, i.e. crack free concrete was obtained. Figure (4-9) and (4-10) show that same trends as those of figure (4-7) and (4-8).

Table (4-6): Restrained shrinkage of plain and crimped fibre reinforced concrete beams.

Age (days)	Cracking width (mm)					
	Fibre Addition (%)					
	0.00	0.25	0.50	1.00	1.50	2.00
3	0.10	0.10	0.08	0.00	0.00	0.00
7	0.28	0.25	0.18	0.10	0.00	0.00
9	0.37	0.32	0.25	0.20	0.05	0.00
11	0.60	0.45	0.30	0.28	0.15	0.02
15	0.80	0.52	0.35	0.30	0.25	0.10
30	0.85	0.55	0.40	0.30	0.30	0.15
45	0.90	0.60	0.40	0.32	0.35	0.20
60	0.90	0.60	0.40	0.32	0.35	0.22
70	0.90	0.60	0.40	0.32	0.35	0.22

Table (4-7): Restrained shrinkage of plain and straight fibre reinforced concrete beams.

Age (days)	Cracking width (mm)		
	Fibre Addition (%)		
	0.00	1.5 S_f	2.0 S_f
3	0.10	0.00	0.00
7	0.30	0.00	0.00
15	0.55	0.05	0.00
20	0.85	0.125	0.00
30	0.95	0.20	0.00
45	0.95	0.20	0.00
60	0.96	0.23	0.00
70	0.96	0.23	0.00

Table (4-8): Restrained shrinkage of plain and 1.5% fibre reinforced concrete beams.

Age (days)	Cracking width (mm)		
	Fibre Addition (%)		
	0.00	1.5 C_f	1.5 S_f
3	0.17	0.00	0.00
8	0.30	0.05	0.00
13	0.55	0.17	0.065
15	0.65	0.25	0.10
30	0.88	0.30	0.20
45	0.90	0.35	0.20
60	0.90	0.35	0.23
70	0.90	0.35	0.23

Table (4-9): Restrained shrinkage of plain and 2% crimped and straight fibre reinforced concrete beams.

Age (days)	Cracking width (mm)		
	Fibre Addition (%)		
	0.00	2.0 C_f	2.0 S_f
4	0.15	0.00	0.00
7	0.32	0.00	0.00
11	0.55	0.02	0.00
30	0.80	0.15	0.00
45	0.88	0.20	0.00
60	0.90	0.22	0.00
70	0.90	0.22	0.00

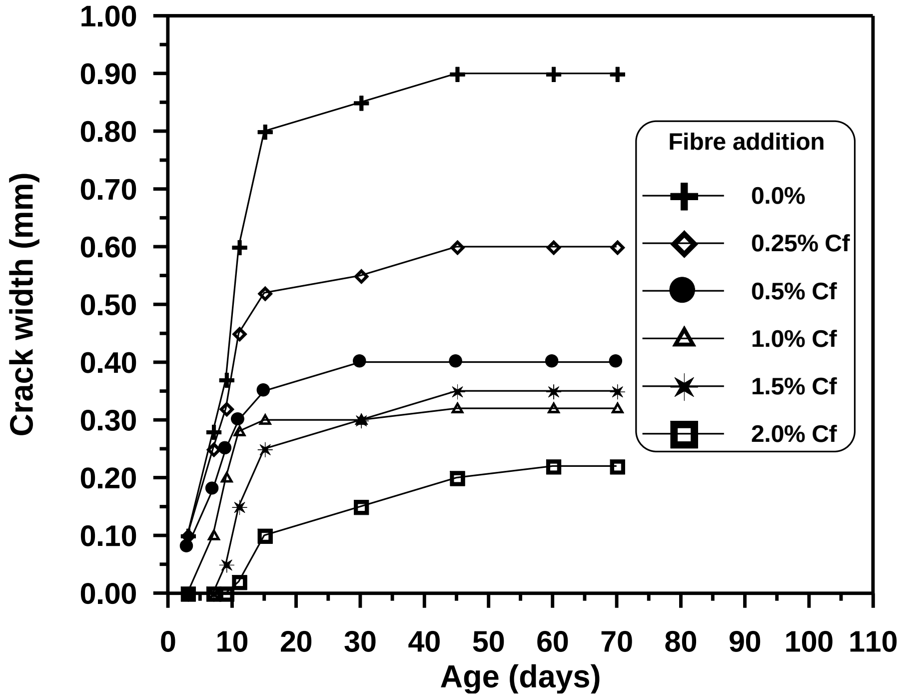


Figure (4-8): Relationship between crack width of plain and crimped fibre reinforced concrete beams with age

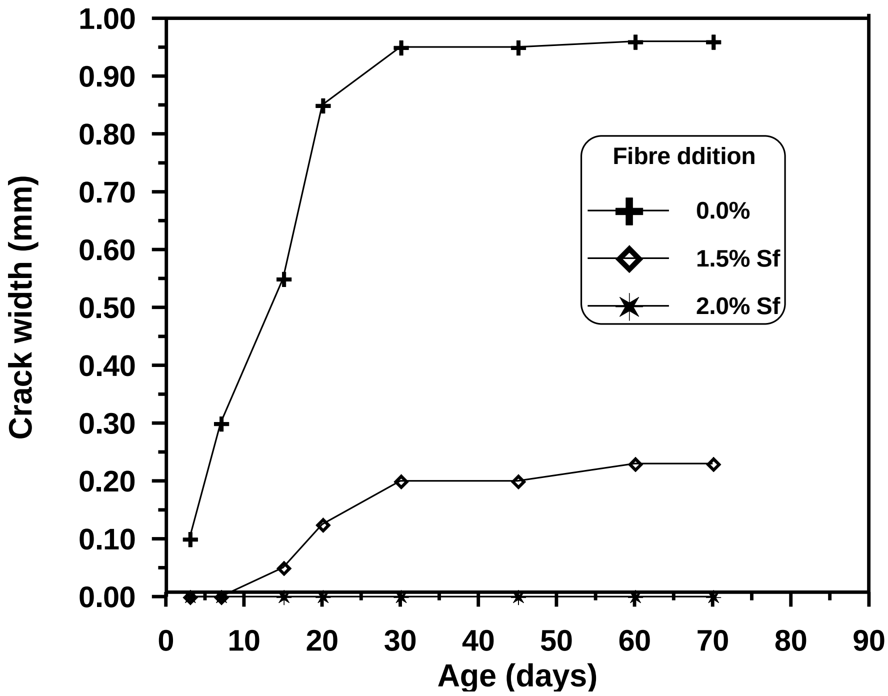


Figure (4-9): Relationship between crack width of plain and straight fiber reinforced concrete beams with age

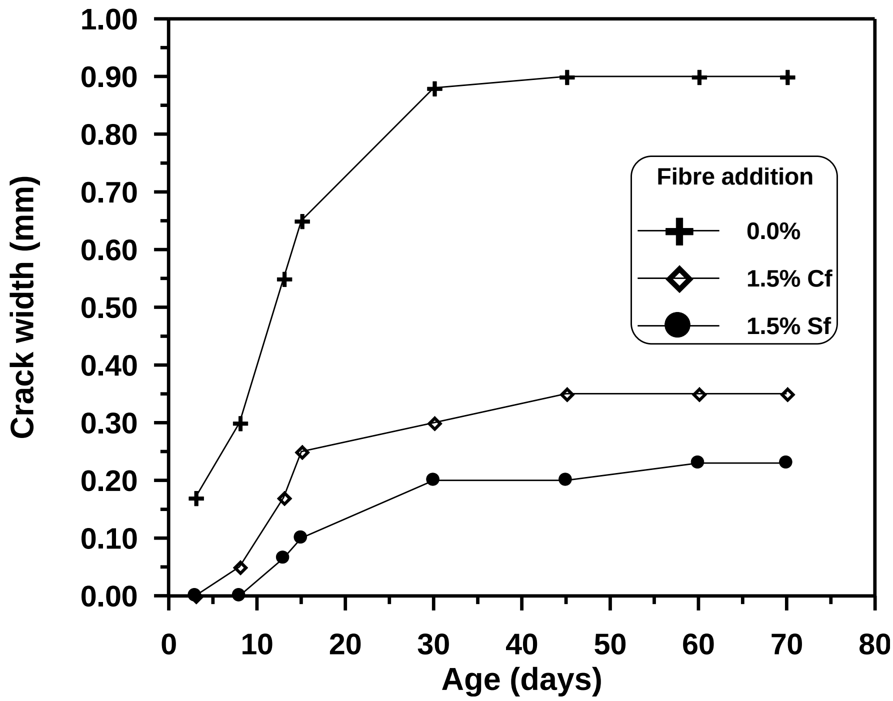


Figure (4-10): Relationship between crack width of plain and 1.5% crimped and straight fiber reinforced concrete beams with age

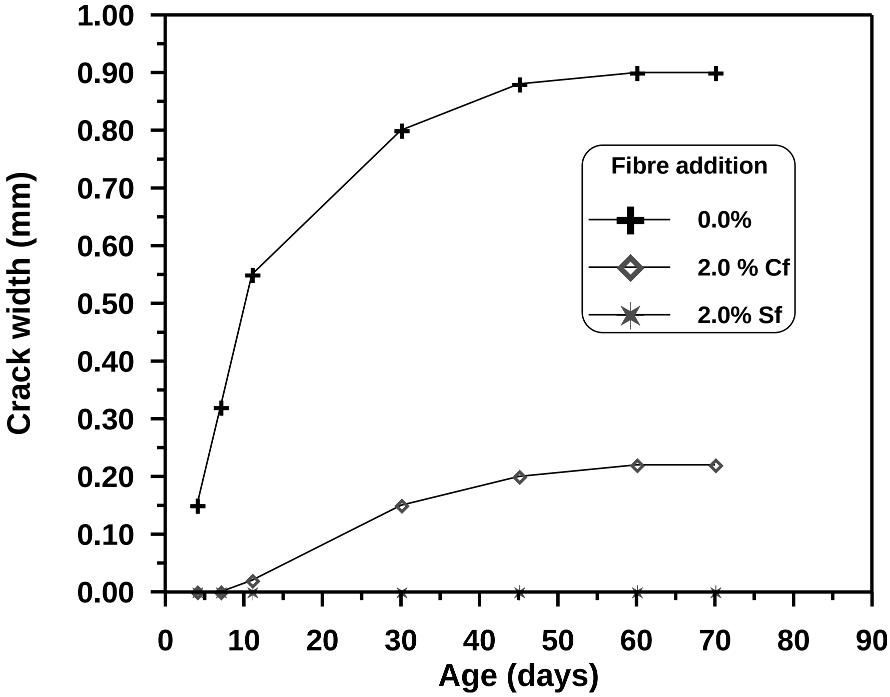


Figure (4-11): Relationship between crack width of plain and 2.0% crimped and straight fiber reinforced concrete beams with age

Conclusions and Future Works

Based on the results obtained from testing in this work, the following conclusions can be drawn:-

1) It was found that the compressive strength decreases with increasing fibre content for both types of fibre there is a similar trend for the splitting tensile strength.
2) Based on the results obtained, it was found that the compressive strength maximum at 1.5% crimped fibre content, but its decreases when fibre content increases.
3) Cracking time increases with increased fibres addition. This increase is dependent on the type of fibre added.
4) Tensile strain capacity of concrete decreases with fibre addition. The greater the fibre addition, the greater the decreases in tensile strain capacity. This is contrary to conclusions obtained in previous literature.
5) It was noticed that the decrease in tensile strain capacity with increased fibre content is dependent on the type of fibre. Straight case less reduction in tensile strain capacity than crimped fibres.
6) Addition of steel fibres reduces the shrinkage and shrinkage crack width of concrete. The higher the fibre content, in the range of (0.5% to 2.0%) of the volume of concrete, the lower is the shrinkage.
7) Based on the results obtained it was found that the reduction shrinkage is dependent on the type of fibres added. With crimped fibres up to (52%) reduction in shrinkage was obtained and up to (64%) reduction in shrinkage was obtained with straight fibres.

Recommendation and Futures Works

The following recommendations are subjected to further researches.

1) Studying the effect of fire flame on mechanical properties of reinforced concrete beams.

2) Studying the effect of fibre content on the mechanical properties of reinforced concrete slabs before and after exposure to fire flame.
3) Research is required to studying the combination effect of the fire flame and fibre content on the behavior of reinforced concrete beams and slabs.

Table (A-1): Physical Properties of the Cement.

Physical Properties	Test results	I.O.S.5 :1984(68) :Limits
Fineness, Blain, cm2/gm	3090	≥2300
Setting time, Vicat's method Initial hrs:min Final hrs:min	 1:57 3:20	 ≥1:0 ≤10:0
Compressive strength of 70.7 mm cube, Mpa 3 days 7 days	 20 27.5	 ≥15 ≥23

Table (A-2): Physical Properties of the Cement

Sieve size (mm)	Percent Passing	I.O.S. 45:1984[15] limits zone(3)
9.50	100	100
4.75	94	90-100
2.36	92	85-100
1.18	78	75-100
0.60	52	60-79
0.30	23	12-40
0.15	0	0-10
Properties	Test rest results	I.O.S. 45:1984[15] limits zone(3)
Sulphate content, SO_3	0.27	$\leq$ 0.5
specific gravity	2.60	-
Absorption	1.75	-

Table [A-3]: properties of the sand

Oxide	**(%)**	**I.O.S.5 :1984[14] :Limits**
Cao	61.26	---
Sio_2	20.8	---
Fe_2O_3	3.2	---
AL_2O_3	6.12	---
MgO	4.4	≤5
SO_3	2.33	≤2.8
Free lime	0.76	---
L.O.I	1.75	≤4
I.R.	0.61	≤1.5
Compound Composition	**(%)**	**I.O.S.5 :1984[14] :Limits**
C_3S	38.74	---
C_2S	30.52	---
C_3A	9.32	---
C_4AF	9.73	---
L.S.F	0.88	0.66-1.02

Table [A-4]: properties of the gravel

Sieve size (mm)	Percent Passing	I.O.S. 45:1984[15] limits zone(3)
37.5	100	100
20.0	7	95-100
9.50	53	30-60
4.75	3	0-10
Properties	Test rest results	I.O.S. 45:1984[15] limits
Sulphate content, So3	0.07	$\leq$ 0.1
specific gravity	2.64	-
Absorption	0.70	-

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تأثير نوع و شكل الألياف الحديدية على بعض الخواص الميكانيكية للخرسانة المسلحة

الخلاصة

يتناول هذا البحث دراسة تأثير إضافة الألياف الحديدية على بعض خواص الخرسانة المسلحة مثل مقاومة الانضغاط ومقاومة الشد للانشطار (شد الانشطار) والانكماش وعرض التشققات وزمن حدوث هذه التشققات ودراسة تأثير شكل الألياف الحديدية على هذه الخواص أيضا .

لقد أجريت الفحوصات على عتبات اعتيادية و مسلحة مقيدة النهايات و لمكعبات خرسانية بأبعاد (150 ملم) واسطوانات خرسانية بأبعاد (100*200 ملم) لقد تم استخدام نوعين من الألياف الحديدية في هذا البحث وبقيمة حجمية تتراوح بين (0.25 –2)% واعتماد ا على نتائج هذا البحث يمكن الاستنساخ بان أقصى مقاومة انضغاط واقصى شد انشطار للخرسانة يكون عند الإضافة للألياف الحديدية الملتوية (1.5 %).ومن خلال النتائج المختبرية وجد ان مقاومة الانضغاط و مقاومة الشد للانشطار للخرسانة تتناقص بزيادة محتوى الالياف الحديدية المضافة ولكن اقصى قيمة للمقاومة وجدت عند نسبة 1.5%من الالياف الملتوية.

من خلال النتائج المختبرية تبين إن إضافة الألياف الحديدية يؤدي الى نقصان الانكماش الحاصل بالخرسانة وكذلك نقصان عرض التشققات وان هذا النقصان الحاصل يعتمد أيضا على شكل هذه الألياف الحديدية المضافة والمستخدمة .