The Effect of Adding Chicken Wire as Steel Fibre on Some Properties of Polymer Concrete

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Abstract
This research includes the study of the effect of adding steel fibres resulting from cutting chicken wire (which is available in Iraqi markets now) as fibres added to the polymer concrete. These fibres were added with percentages of concrete volumes. These percentages were (0.5%) and (1%). Reference concrete mix was also made for comparative reasons. From the results, it can be noted that the increasing of compressive strength of SFPC1 comparing with RPC at 28 days equal to 9.90%, whereas the increasing of compressive strength of SFPC2 comparing with RPC at 28 days is equal to 15.48%. The increasing of splitting strength of SFPC1 comparing with RPC at 28 days equal to 15.50%, whereas the increasing of SFPC2 comparing with RPC at 28 days is equal to 21.40%. The increasing of flexural strength of SFPC1 comparing with RPC at 28 days equal to 10.80%, whereas the increasing of SFPC2 comparing with RPC at 28 days is equal to 20.63%.

Results proved that adding of steel fibres with these percentages lead to improvements in compressive strength, splitting strength and flexural strength of concretes containing steel fibres, but the improvement in flexural strength appeared more clearly. Results proved also an increasing in densities of fibre concrete samples according to these made of reference mix.

تأثير أضافة أسلاك أقفاص الدجاج كألياف حديدية على بعض خصائص الخرسانة البوليمرية

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الخلاصة
يتضمن هذا البحث دراسة تأثير اضافة نواتج التقطيع اليدوي للاسلاك اقفاص الدجاج (المتوفرة في السوق العراقية حالياً) كألياف حديدية مضافة الى الخرسانة البوليمرية وبنسب من حجم الخلطة على مقاومة الخرسانة للانضغاط والانثناء وعلى كثافة تلك الخرسانة. تمت اضافة الالياف الحديدية بنسب (0.5%) و (1%) من حجم الخلطات الخرسانية ، كما وتم استخدام خلطة خرسانية مرجعية لغرض المقارنة.

اظهرت النتائج تحسناً في الخواص الميكانيكية للخرسانة الحاوية على الالياف حيديدية مقارنة بالخرسانة المرجعية وكان التأثير الاكثر وضوحاً في تحسين مقاومة الانثناء و الانشطار للخرسانة الحاوية على الالياف. كما اظهرت النتائج زيادة في مقاومة الانضغاط و كثافة الخرسانة الحاوية على الالياف حيديدية مقارنة بالخرسانة المرجعية.

1. Introduction
Fibre concrete may be defined as a composite material made with Portland cement, aggregate, and incorporating discrete discontinuous fibres.

Plain, unreinforced concretes a brittle material, with a low strain capacity. The randomly distributes discontinuous fibres is to bridge across the cracks that develop provides some post-cracking "ductility". If the fibres are sufficiently strong, sufficiently bonded to material, and permit the FRC (Fibre Reinforced Concrete) to carry significant stresses over a relatively large strain capacity in the post-cracking stage.

There are, of course, other (and probably cheaper) ways of increasing the strength of concrete, the real contribution of the fibres is to increase the toughness of the concrete (defined as some function of the area under the load vs. deflection curve), under any type of loading. That is, the fibres tend to increase the strain at peak load, and provide a great deal of energy absorption in post-peak portion of the load vs. deflection curve.[1]

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2. Steel-Fibre Concrete

It is now well established that one of the important properties of steel fibre reinforced concrete (SFRC) is its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fibre composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading; and the fibres are able to hold the matrix together even after extensive cracking. The net result of all these is to impart to the fibre composite pronounced post-cracking ductility which is unheard of in ordinary concrete. The transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fibre composite and its ability to withstand repeatedly applied, shock or impact loading.

Fibres 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 fibres, the fibres have little effect on compressive strength. However, the fibres do substantially increase the post-cracking ductility, or energy absorption of the material.(2)

Fibres aligned in the direction of the tensile stress may bring about very large increases in direct tensile strength, as high as 133% for 5% of smooth, straight steel fibres. However, for more or less randomly distributed fibres, the increase in strength is much smaller, ranging from as little as no increase in some instances to perhaps 60%, with many investigations indicating intermediate values. Splitting-tension test of SFRC show similar result. Thus, adding fibres merely to increase the direct tensile strength is probably not worthwhile. However, as in compression, steel fibres do lead to major increases in the post-cracking behaviour or toughness of the composites. (2)

Steel fibres are generally found to have 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 increases in flexural strength is particularly sensitive, not only to the fibre volume, but also to the aspect ratio of the fibres, with higher aspect ratio leading to larger strength increases.(2)

For all of the empirical measures of toughness, fibres with better bond characteristics (i.e. deformed fibres, or fibres with greater aspect ratio) give higher toughness values than do smooth, straight fibres at the same volume concentrations. (3)

3. Polymer Concrete (PC)

A continuous research by concrete technology to understand, improve and develop the properties of concrete has resulted in a new type of concrete known as "Polymer Concrete". To study and use polymer in concrete, practical researches and development have been carried out in various countries, particularly Japan, USA, and Germany in the past 40 years.

SBR polymer is most widely used in concrete. The proportion of SBR latex, combined with low water /cement ratio produces concrete that has improved flexural, tensile, bond strength, lower modulus of elasticity and reduced permeability characteristics compared with conventional concrete of similar mix design. Compressive strength is typically unchanged.[(4)]

Folice, R. J. and Vlastimirs M S. [(5)], tested (180) concrete samples, different in size and shape. All properties of modified concrete were analyzed depending on the quantity of polymer used. The following results were obtained from the tests: [(5)]

- The greater effect on physical and mechanical properties of latex modified concrete was achieved at the optimal combination of wet and dry curing, i.e., curing in dry environment.
- Compressive strength was slightly increased with the increase of polymer/cement ratio (1 to 7 percent).
- Tensile strength increased with the increase of polymer/cement.
- Ratio and the correlation is in the form of a straight line. The increase of flexural strength for concrete modified with 7.5 percent of polymer admixture was (40) percent in relation to the reference concrete.
- Water absorption decreased with the increase of polymer/cement ratio.
- Shrinkage of the modified concrete with 7.5 percent of polymer admixture on the cement mass was almost 50 percent less than the shrinkage of the reference concrete.
- Adhesion between reinforcement and concrete increases with the polymer/cement ratio increase.
- The effect of latex quantity of 7.5 percent on the cement mass has not significantly influenced the value of static and dynamic modules of elasticity.

Al-Hadithi, [(6)] studied the properties and behaviour of no-fine concrete using (10 mm) maximum size of aggregates improved by SBR polymer. The polymer was added as percentage of cement weight 5%, 7.5% and 10%. It was recorded an appreciable improvement in compressive, flexural strength and density of polymer modified no-lines concrete corresponding to reference no-fines concrete.

Al-Atiyah,[(7)] studied the effect of SBR polymer on stress-strain relationship of no-fine concrete under compression and also the effect of polymer/ cement ratios on density. The polymer was added as percentages of cement weight and the ratios of polymer were 5%, 7.5% and 10%, and reference mixes were made for every case. He found that the SBR improved the compressive strength and made no-fines concrete less strained than in reference mixes. The density increased when P/C ratio increased.

4. Materials

4.1 Cement

Ordinary Portland Cement (OPC) ASTM Type I from Kubaisa cement factory is used. The cement is complied to Iraqi specification no. 5/ 1984[(8).]

4.2 Fine Aggregate

Natural sand from a region in Al-Anbar Governorate was used in production of concrete specimens used in this study. Results of sieve analysis of this sand are shown in Table 1.

Specific gravity and absorption of fine sand used were calculated according to ASTM-Designation: C 128-88[(9)] and they were equal to 2.65 and 3.2% respectively. The sulfate content was equal to 0.35%.

Table 1. Sieve Analysis Results of the Sand Used.

Sieve Size	Accumulated percentage passing
4.75mm	83.8
2.36mm	65
1.18mm	52
600micron	30
300micron	9
150micron	1.84
75 micron	0.8

4.3 Coarse Aggregate

Crushed coarse aggregate from a region in Al – Anbar governorate was used for all concrete mixes in this study with maximum size 12.5 mm. the aggregates were conforming to the requirements of the Iraqi specification no. 45-99(10).

Specific gravity was equal to 2.79 and sulfate content was equal to 0.075%.

4.4 Mixing Water

Ordinary tap water was used in this work for all concrete mixes and curing of specimens.

4.5 Steel Fibres

Steel fibres with (15 – 30) mm length and 0.5 mm diameter were obtained by cutting chicken wires are used in this study.

4.6 Polymer

Styrene butadiene rubber (SBR) is used as polymer modifier in this study. Styrene butadiene, an elastomeric polymer, is the copolymerized product of two monomers, styrene and butadiene. Latex is typically included in concrete in the form of a colloidal suspension polymer in water. This polymer is usually a milky-white fluid. The Gulf International Chemicals Company, Oman, manufactured this polymer and the typical properties of SBR polymer is shown in Table 2.

Table 2. Typical Properties of Styrene Butadiene Rubber (SBR) Polymer.

No	Properties	Description
1	Appearance	White emulsion
2	Specific Gravity	1.03 ± 0.02@ 25° C
3	pH Value	9±2
4	Freeze/Thaw Resistance	Excellent
5	Chloride Content	Nil
6	Flammability	Non-flammable
7	Compatibility	Can be used with all types of Portland cement

*Properties are obtained from the product catalogue (18)

5. Mixing and Compaction of Concrete

Mixing operations were made in the concrete laboratory in the civil engineering department of Anbar University. A 0.1 m^3 pan mixer was used. Pouring the coarse aggregates made mixing and cement in two alternate times and mixing them dry while adding the fibres until a homogenous dry mix is obtained. The water is added then and mixing continued until final mix is obtained.

The concrete mix is poured, in three layers, in the molds. An electrical vibrator made compaction for not more than 10 sec.

6. Curing

The specimens were unmolded after 24 hrs .in laboratory. They were submerged in water to the time of test.

7. The Mixes

Table 3. Mix Proportions of Materials Used in this Work for Making One Cubic Meter of Concrete.

Symbol	Cement (kg)	Gravel (kg)	Sand (kg)	Polymer content(%) by cement weight	Plastic Fibres (%) of Mixture Volume	W/C %
RPC	390	929	728	10	0.0	0.43
SFPC1	390	929	728	10	0.5	0.43
SRPC2	390	929	728	10	1.0	0.43

8. Tests

8.1 Compressive Strength Test

Compressive strength was determined using (100X100X100) mm cubes according to B.S.1881 part 116 [11] .ELE machine with a capacity of (1000) KN was used for that test. The average compressive strength of three cubes was recorded for each testing age (7, 14 and 28 days).

8.2 Splitting Strength Test

Concrete cylinders of (100X200) mm were prepared according to ASTM C192-88[12]. The test was carried out according to ASTM C496-86[13] using ELE (50) KN capacity machine. Average of two cylinders was obtained for each testing age (7, 14 and 28) days.

The ultimate splitting strength was calculated using the following equations:

$$f_{st} = 2P/dL$$

where:

f_{st}=splitting strength, MPa

P=Maximum applied load indicated by testing machine, N

L= Span length, (mm)

d=Average depth of specimen, mm

8.3 Flexural Strength Test

(100X100X500) mm Concrete Prisms were prepared according to ASTM C192-88(9). Two point load test was carried out according to ASTM C78-94[14] using ELE (50)KN capacity machine. Average modulus of rupture of two prisms was obtained for each testing age (7, 14 and 28) days.

The ultimate flexural strength (modulus of rupture) was calculated using the following equations:

$$f_r = PL/bd^2$$

where a is greater than 166.67mm

or

$$f_r = 3Pa/bd^2$$

where a is less than 166.67mm

f_r=Modulus of rupture, MPa

P=Maximum applied load indicated by testing machine, N

L= Span length, (mm)

b=Average width of specimen, mm

d=Average depth of specimen, mm

a=Average distance between line of fracture and the nearest support measured on the tension surface of the beam, mm.

8.4 Density

The weight of every specimen was recorded air-dry and dimension prior to test.

9. Results and Discussion

9.1 Compressive Strength

Table 4 shows the results of compressive strength test of this study. Figs. (1) and (2) show the relationship between compressive strength with age. From these figures it can be seen that, the compressive strength of all specimens increases with time. The compressive strength of all specimens increases with increasing the percentage of steel fibres. From the results, it can be noted that the increasing of compressive strength of SFPC1 comparing with RPC at 28 days is equal to 9.90%, whereas the increasing of SFPC2 comparing with RPC at 28 days is equal to 15.48%. From these figures it can be noticed that, adding of fibres to concrete with these percentages leads to improving the compressive strength of concrete. This may be due to the effect of the polymer to reduce w/c ratio, due to lesser-entrapped air voids, the better performance of concrete mixes containing SBR, the capability of steel fibre to delay the unstable development of microcracking, as well as limitation the propagation of these micro-crack and composite effect for concrete and steel fibres under load *i.e.* associated with the steel fibre resistance to the external load.

Table 4. The Results of Compressive Strength Test*

Symbol	Compressive Strength (MPa)		
	7 days	14 days	28 days
RPC	27.30	30.67	39.40
SFPC1	30.03	36.66	43.30
SRPC2	31.16	40.06	45.50

* The results above is average of three cubes

9.2 Splitting Strength

Table 5 shows the results of splitting strength test of this study. Figs. (3) and (4) show the relationship between splitting strength with age. From these figures it can be seen that, the splitting strength of all specimens increases with time. From the results, it can be noted that the increasing of splitting strength of SFPC1 comparing with RPC at 28 days equal to 15.50%, whereas the increasing of SFPC2 comparing with RPC at 28 days is equal to 21.40%. It is appearing from these figures that adding of fibres to concrete with these percentages leads to a good improving in the splitting strength of concrete and these increasing relatively with an increasing in fibres percentages. These increases in splitting strength might be due to the composite effect of the polymer and steel fibres, which lead to bridge the cracks, resisting the formation of micro-crack and the high tensile strength of polymer itself leading to an overall improvement in the cement – aggregate bonds.

Table 5. The Results of Splitting Strength Test.

Symbol	Compressive Strength (MPa)		
	7 days	14 days	28 days
RPC	3.33	4.11	5.23
SFPC1	3.67	4.87	6.04
SRPC2	4.01	5.56	6.35

* The results above is average of three prisms

9.3 Flexural Strength

Table 6 shows the results of flexural strength test of this study. Figs. (5) and (6) show the relationship between flexural strength with age. From these figures it can be seen that, the flexural strength of all specimens increases with time. From the results, it can be noted that the increasing of flexural strength of SFPC1 comparing with RPC at 28 days equal to 10.80%, whereas the increasing of SFPC2 comparing with RPC at 28 days is equal to 20.63%. It is appearing from these figures that adding of fibres to concrete with these percentages leads to a good improving in the flexural strength of concrete and these increasing relatively with an increasing in fibres percentages. These increases in flexural strength might be due to the bridging the cracks, the development of bonding property of polymer film on the surface of the concrete and the interface with other material which lead to an increase in the tensile strength of concrete and hence its flexural strength, and to the role of steel fibres in releasing fracture energy around the crack tips, which required to extent crack growing by transferring it from side to another side.

Table 6. The Results Of Flexural Strength Test.

Symbol	Flexural Strength (MPa)		
	7 days	14 days	28 days
RPC	4.11	5.28	6.30
SFPC1	4.45	5.88	6.98
SRPC2	5.23	6.09	7.6

* The results above is average of three prisms

9.4 Density

Table 7 shows the results of flexural strength test of this study. The relationship between density at (28) day age and fibre content ratio is shown in Fig. (5). It can be seen that the density at (28) day increasing relatively with an increasing in fibre content ratio. In all mixes there were increases in density value in fibre concrete compared with reference mix.

The relationship between flexural strength and density is showing by Fig. (6) and this Figure showing an increasing in flexural strength with an increasing in density.

Table 7. The Results of Density Test.

Symbol	Density (kg/m^3)		
	7 days	14 days	28 days
RPC	2340	2410	2488
SFPC1	2398	2427	2495
SRPC2	2406	2478	2500

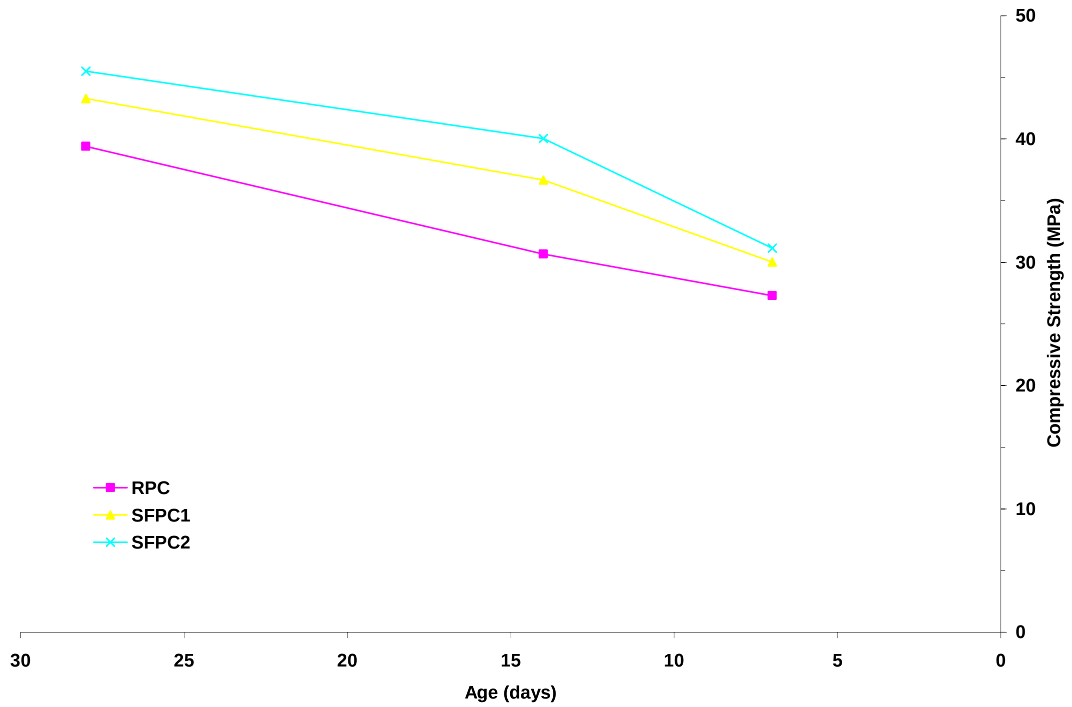

Fig. 1. The relationship between compressive strength and age for all mixes.

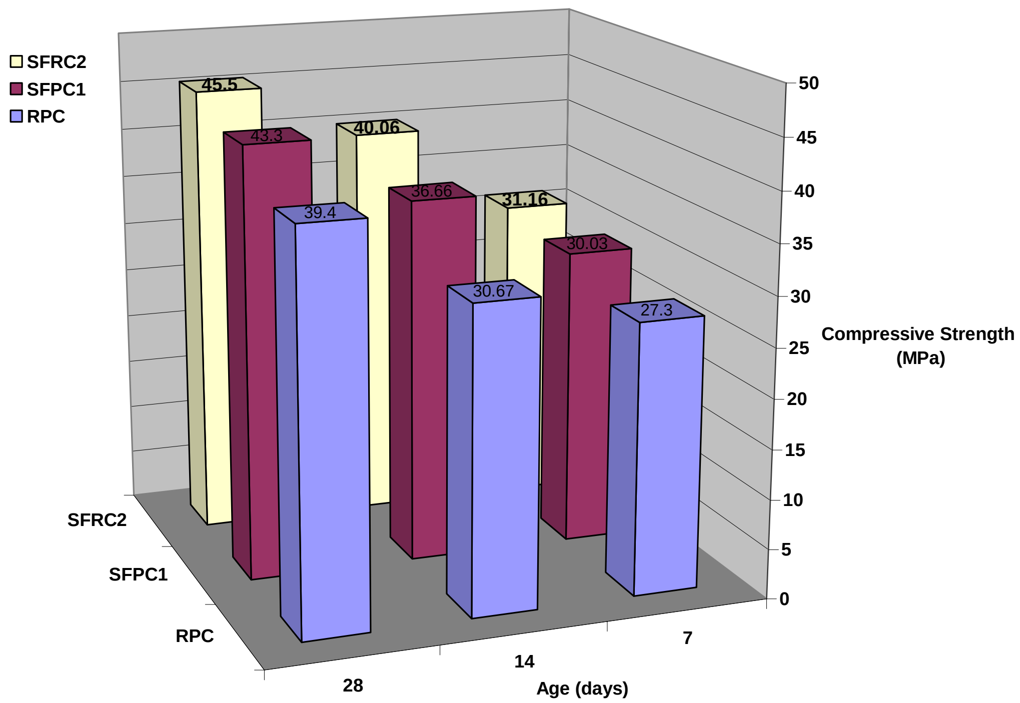

Fig. 2. Development of Compressive Strengths for all Concrete Mixes at All Ages.

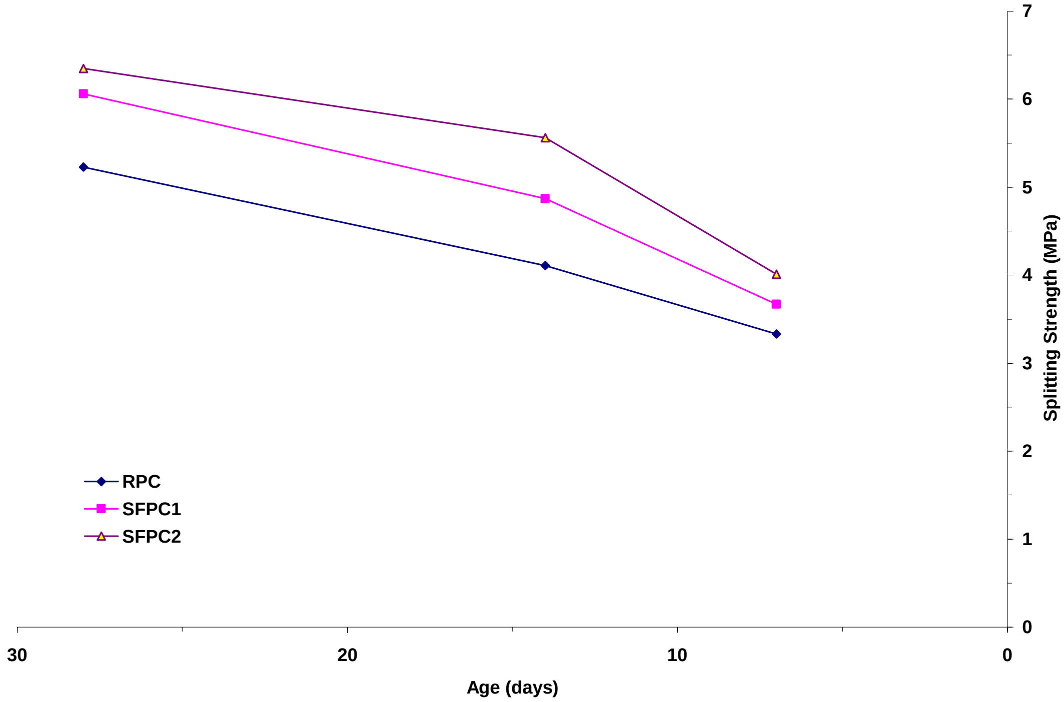

Fig. 3. The Relationship between Splitting Strength and Age for All Mixes.

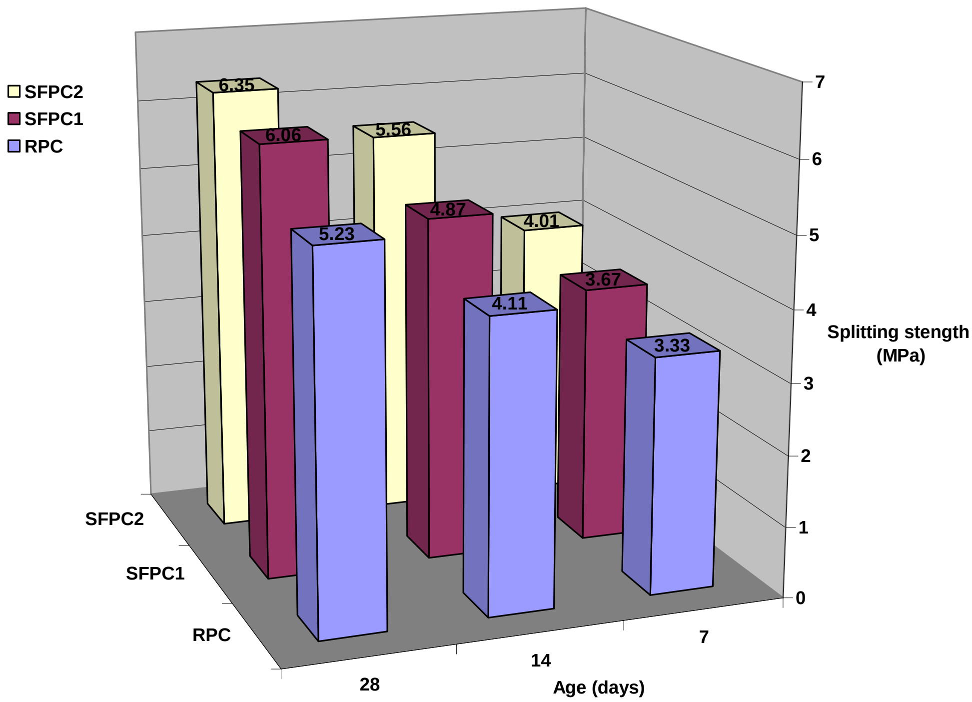

Fig. 4. Development of Splitting Strengths for all Concrete Mixes at All Ages.

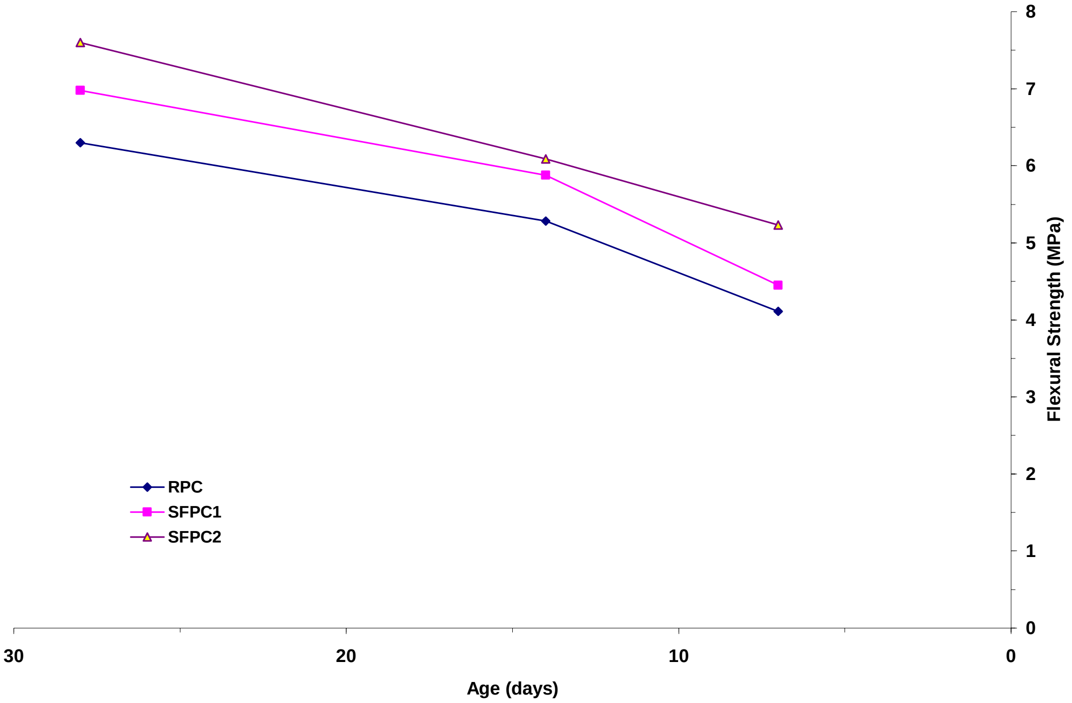

Fig. 5. The Relationship between Flexural Strength and Age for All Mixes.

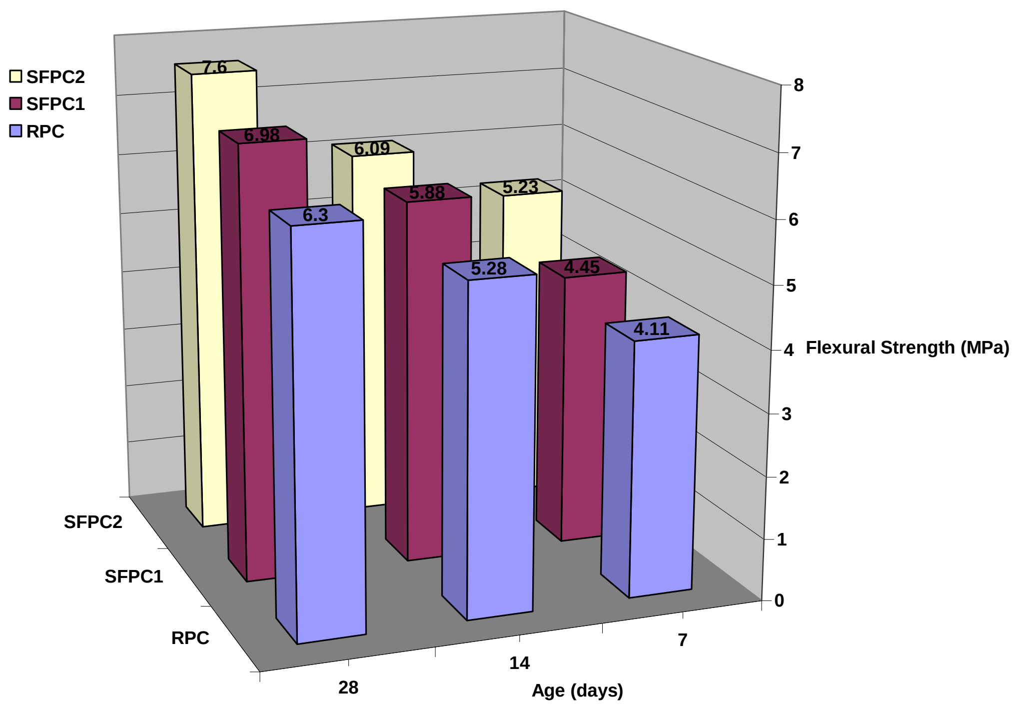

Fig. 6. Development of Flexural Strengths for all Concrete Mixes at All Ages.

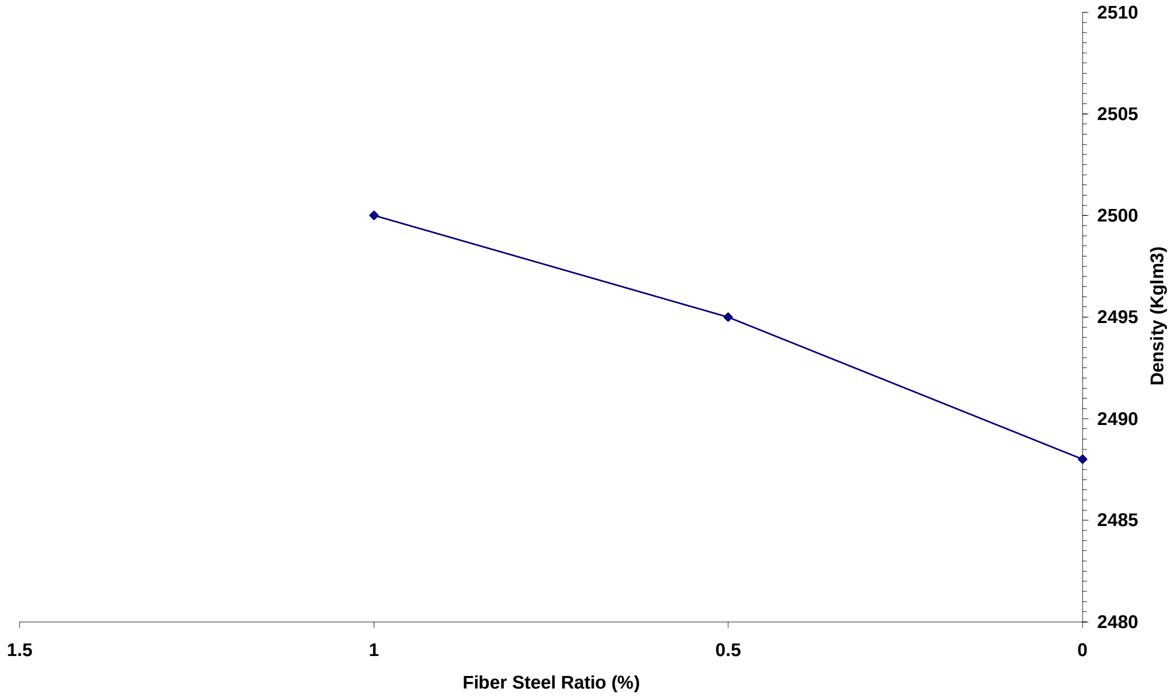

Fig. 7. The relationship between density and fibre content for all mixes.

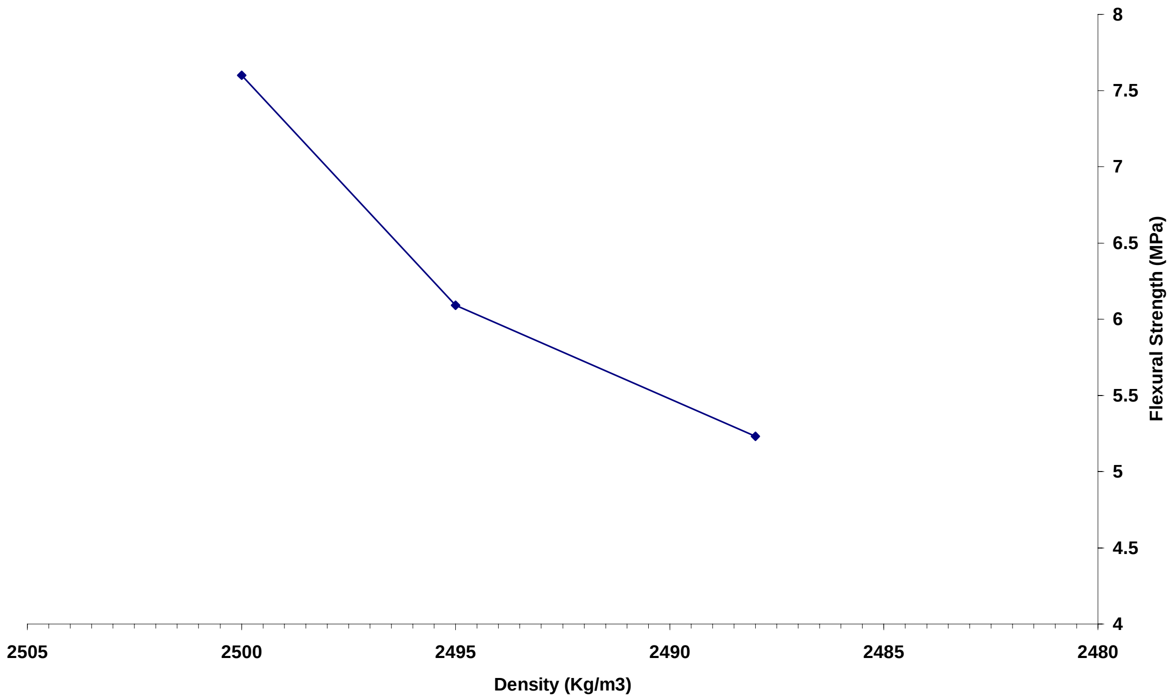

Fig. 8. The relationship between flexural strength and density for all mixes.

10. Conclusions

1. The compressive strength of all specimens increases with time. The compressive strength of all specimens increases with increasing the percentage of steel fibres. From the results, it can be noted that the increasing of SFPC1 comparing with RPC at 28 days equal to 9.90%, whereas the increasing of SFPC2 comparing with RPC at 28 days is equal to 15.48%.
2. The splitting strength of all specimens increases with time. The spliting strength of all specimens increases with increasing the percentage of steel fibres. From the results, it can be noted that the increasing of SFPC1 comparing with RPC at 28 days equal to 15.50%, whereas the increasing of SFPC2 comparing with RPC at 28 days is equal to 21.40%.
3. The flexural strength of all specimens increases with time. The flexural strength of all specimens increases with increasing the percentage of steel fibres. From the results, it can be noted that the increasing of SFPC1 comparing with RPC at 28 days equal to 10.80%, whereas the increasing of SFPC2 comparing with RPC at 28 days is equal to 20.63%.
4. It can be seen that the density increasing relatively with an increasing in fibre content ratio compared with references mixes.

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