Effect of Petroleum Products on Steel Fiber Reinforced Concrete

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ABSTRACT

This Investigation aims to study the effect of adding Steel fibers with different volume fractions V_f (o.5, 0.75, and 1% by volume of concrete) with aspect ratio 100 on mechanical properties of concrete, and also finding the influence of petroleum products (Kerosene and Diesel) on mechanical properties of Steel Fiber Reinforced Concrete (SFRC).

The experimental work consists of two groups: group one consists of specimens (cubes and prisms) plain and concrete reinforced with steel fiber exposed to continuous curing with water. Group two consists of specimens (cubes and prisms) plain and concrete reinforced with steel fiber exposed to kerosene and diesel after curing them in water for 28 days before exposure.

The results of all tests refer that the specimens (plain and reinforced concrete with steel fiber with different volume fraction) exposed to kerosene were better than the specimens (plain and reinforced concrete with steel fiber with different volume fraction) exposed to diesel.

Key words: Steel Fibers, Kerosene, Diesel, Reinforced concrete

تأثير المشتقات النفطيه على الخرسانه المسلحه بالالياف الحديديه

الخلاصه

الهدف من هذا البحث هو دراسه تاثير اضافه الياف الحديد بنسبه مختلفه (0.5، 0.75، و 1% من حجم الخرسانه) دو نسبه باعيه 100 على الخواص الميكانيكيه للخرسانه، وكذلك أيجاد تأثير المشتقات النفطيه (النفط الابيض وزيت الكاز) على الخواص الميكانيكيه للخرسانه المسلحه بالالياف الحديديه.

العمل المختبري مكون من مجموعتين : المجموعه الاولى تتضمن نمادج (مكعبات ومواشير) من الخرسانه الاعتياديه والمسلحه بالالياف الحديد معرضه الى الانضاج المستمر للماء. اما المجموعه الثانيه تتضمن نمادج (مكعبات ومواشير) من الخرسانه الاعتياديه والمسلحه بالالياف الحديد معرضه الى النفط الابيض او زيت الكاز بعد انضاجها بالماء لمده 28 يوم قبل التعرض.

أشارت جميع نتائج الفحوصات أن النمادج (الغير مسلحه والمسلحه بالياف الحديد بنسب مختلفه) المعرضه للنفط الابيض كانت افضل من نتائج النمادج (الغير مسلحه والمسلحه بالياف الحديد بنسب مختلفه) المعرضه لزيت الكاز

INTRODUCTION

The long life of many reinforced concrete structures which have been exposed to aggressive environment for years shows that concrete has a significant durability in these environments .This has encouraged the tremendous developments in the use of large concrete structures, reinforced or pre-stressed, for the production, storage and transportation of oil products, to overcome the shortage in steel materials in some parts of the world. A Reinforced concrete tanks are used instead of steel tanks for petroleum products storage. Change from steel to concrete for storage purpose was due to low cost of repair, maintenance, and construction. In addition, concrete offers considerable resistance to fire and explosive during war times.

Steel tanks and pipes have traditionally been used for storage and transportation of petroleum products around the world. However, in many countries especially those which do not have steel industry, storage in these structures could occur. In addition, the high costs of construction and maintenance, the need for larger capacities and safety requirements for steel tanks have urged the people concerned to look for new alternatives of constructional materials. Concrete oil-storage tanks have been tried for at least seventy years and would have many advantages if adequate impermeability could be assured without the use of expensive impermeable liners. The critical storage and cost of steel during the Second World War expanded progressively the use of concrete for the construction of oil tanks. Before 1914, many concrete tanks were built in the USA for storage of heavy oils and during the Second World War the USA navy built concrete tanks for fuel oil Storage **(Spamer 1944)&(Shepard 1944)**.

The main problems that restrict the successful use of concrete to store fuel oil are: the leakage of oils especially the lighter products (that having specific gravity 0.875 at temperature 15C) through the pore structure, shrinkage cracks and joints **(Lea 2004)**.

However the serviceability of reinforced concrete storage containers necessitates control of cracking and impermeability. Generally, concrete materials suffer from the inherent characteristics of low tensile strength and

Tendency to cracks under tensile stresses produced by external loads, shrinkage, creep, or thermal gradients. In most cases, long term loading extends the magnitude of cracks in both plain and reinforced concrete **(Abdul- Ahad et al., 2000)**.

The advantages of using reinforced concrete tanks as follows: **(Concrete Storage Structure 1983)**

- The availability and low cost of raw materials results in economic construction costs.
- A remarkable durability in almost all types of environments resulting in significant reduction in maintenance and maintenance cost accordingly.
- Good fire and earthquake resistance, thermal, impact and explosion properties.
- Suitability for underground and under sea storage.
- Constructional flexibility in different shapes and capacities according to the shape of mould lubricated.
- Owing to their dead weights they have the capability of forming buoyant or fixed structures.

The disadvantages of used reinforced concrete tanks as follows: **(Matti 1976) & (Faiyadth 1985)**

- Capability of light petroleum products to penetrate concrete.
- The unavoidable cracking due to shrinkage and thermal movement
- Possibility of fracturing by different settlements.
- Deterioration of the bond between steel and concrete in addition to deterioration in concrete itself if saturated by oils.

RESEARCH SIGNIFICANCE

Concrete is the most commonly used material in construction industry. There are a number of reasons for this such as high strength, ease of production, low cost, good compatibility with other materials, especially with steel, durability under aggressive conditions. Ordinary concrete includes cracks with large width and has low tensile or flexure strength, but when Steel Fibers added to concrete can improve its properties like compressive strength, flexural strength, impact resistance, ability to control cracks and products cracks with small width, and also improve the toughness. The essential objective from this research to study the mechanical properties of steel fiber reinforced concrete when exposed to kerosene and diesel.

STEEL FIBER REINFORCED CONCRETE

Although concrete is a widely used construction material, it has major disadvantages such as a low tensile strength and low strength to weight ratio, and it is liable to cracking **(Cement& Concrete Institute 2010).**

Fiber reinforced concrete (FRC) is Portland cement concrete reinforced with randomly distributed fibers. In FRC, of small fibers are dispersed and distributed randomly in the concrete during mixing, and thus improve concrete properties in all directions. Fibers help to improve the post peak ductility performance, pre-crack tensile strength, fatigue strength, impact strength and eliminate temperature and shrinkage cracks **(Nemati 2010).**

The brittle nature of plain concrete cannot be neglected and an approach to make concrete a ductile material is necessary. In this regard, steel is no doubt a useful reinforcement material for concrete whether it is in the form of a SF or a reinforcing bar. The addition of SF to concrete can improve the tensile strength and ductility, but it will also reduce the workability **(Chang et al., 2009)**

The addition of SF in the concrete mix allows the development of tensile stresses along the entire cracked depth of a section. These stresses can provide the required ultimate bending strength. SF provides also other properties that improve the structural behavior under service loads, for instance **(ACI 544(1996))**

- Crack width reduction
- More uniform distribution of cracks
- Improvement of structural behavior under cyclic loads
- Increase in structural ductility
- Improve impact & abrasion resistance

The use of *SFRC* in building construction has increased continuously due to its better mechanical properties, mainly, the energy absorption capacity. The energy dissipated to pull out the fibers from the cracked concrete is much higher than the Energy dissipated to crack the concrete matrix. Therefore, the energy absorption capacity is the main material property benefited by fiber reinforcement **(Barros and Cruze (1998)).**

PROPERTIES OF STEEL FIBER REINFORCED CONCRETE

1. Compressive Strength

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 substantially increase the post-cracking ductility, or energy absorption of the material (Neves et and Fernades (2006)).

2. Direct Tension

In direct tension, the improvement in strength is significant, with increases of the order of 30 to 40 % reported for the addition of 1.5% by volume of fibers in mortar or concrete (ACI 544 1R-96).

3. Flexural Strength

Increases in the flexural strength of SFRC are substantially greater than in tension or compression because ductile behavior of the SFRC on the tension side of a beam alters the normally elastic distribution of stress and strain over the member depth. The altered stress distribution is essentially plastic in the tension zone and elastic in the compression zone, resulting in a shift of the neutral axis toward the compression zone strength concrete. The main reason for the discrepancy in fiber cement composite is that the post- cracking stress-strain curve on the tensile side of the fiber cement or fiber concrete beam is very different from that in compression (Snyder and Lankard (1972)).

EFFECT OF CRUDE OIL OR ITS PRODUCTS ON PROPERTIES OF PLAIN AND REINFORCED CONCRETE

Meissner et al. (**1944**) have studied the influence of high octane gasoline on mechanical properties of mortar cubes (50 mm) soaked for 180 days. He has investigated that small reduction in compressive strength and no effect in tensile strength for the specimens.

Al – Saraj (**1995**) has studied the mechanical properties of concrete exposed to gas oil and aircraft engine fuel for soaking period of water – cured specimens, he found:

1. The compressive strength of concrete exposed to gasoline and fuel decreased by about 6.8 – 16.3% and 9.2 – 19.3% respectively.
2. The splitting tensile strength was also decreased about 7.3 – 16.8% and 10 – 20.5% for gasoline and fuel exposure respectively
3. The flexural strength was reduced by about 7.3 – 16.8%, and 10 – 20.5% for gasoline and fuel exposure respectively.
4. Modulus of elasticity is reduced by about 17.4-21.9% and 20.5-26.3% for gas oil and fuel, respectively.

Mohammed (**1997**) has investigated that in the field the effectiveness of cured oil on concrete under loadings (30, 40, 50, and 70% from ultimate load) on short and long term loadings. He concluded that:

1. High compressive strength reduction takes place due to higher amount of the oil absorbed relative to its low viscosity reaching 12.52% after 2month soaking.
2. Splitting tensile strength is also reduced due to oil penetration, at lower rate as compared with the compressive strength.
3. Modules of rupture increases due to oil absorption reaching 4% while for loaded specimen, further increase takes place reaching 6 – 8% compared with initial oven dried specimen.
4. The rate of crude oil absorption is high at early stage of soaking and increases slowly with time, and increase moderately at 70% compressive stress / strength ratio.

Rashed (**1998**) has studied the effect of petroleum products (kerosene and gas oil) on steel fiber reinforced concrete. He concluded that:

1. The compressive strength was reduced by about 19 and 20.8% for kerosene and gas oil exposure respectively.
2. The splitting – tensile strength was also reduced by about 18 and 18.3% for kerosene and gas oil exposure respectively.
3. The modulus of rupture of steel fiber concrete exposed to kerosene and gas oil was reduced after 30 days of exposure.

Blaszczynski (**2002**) has investigated that the durability analysis of concrete exposed to a crude oil products environment shows that significant reduction in compressive strength and its bond to reinforcement can occur.

EXPERIMENTAL WORK

Materials

Cement

The cement used is an Ordinary Portland Cement taken from one stocked quantity and supplied from (Taslooja) factory; it is used in casting all specimens throughout the experimental work. It stored in laboratory by plastic containers were used to enclose the cement in order to minimize the effect of humidity throughout the experimental work.
The physical and chemical properties of the cement are shown in Tables (1) and (2) respectively, with the estimated cement

compounds based on Bogue's equations given in (ASTM C 150-00). This cement complied with the (Iraqi specification No.5/1984).

Fine aggregate (Sand)

Al-Akhaidhur well-graded natural sand used of 4.75-mm maximum size was used for concrete mixes of this investigation. Table (3) shows the sieve analysis of this aggregate and Table (4) which represented the properties of the used sand. The grading is lied in (Zone No. 1) and conformed to the limits of Iraqi specification No. 45/1984.

Coarse Aggregate (Gravel)

The Coarse Aggregate used in this research is crushed washed aggregate brought from Al-Nibaii area of maximum size 10mm. **Table (5)** shows the sieve analysis of this aggregate and **Table (6)** which presented the properties of coarse aggregate. It conforms to the **Iraqi specification I.S.O.45/1984**.

Water

Water is used in this research for mixing and curing. It is ordinary potable water for Baghdad City.

Steel Fiber

High tensile steel fibers crimped type was used in this research with 0.5, 0.75 and 1% by volume of concrete (V_f =0.5, 0.75 and 1%). Table (7) shows the properties of the used steel fibers as given by the manufacture.

Petroleum Products
Kerosene and Diesel

Kerosene and diesel product from AL-Daura refinery was used. Tables (8) and (9) show the chemical analysis of the Kerosene and diesel used in this study.

Mix Design and Mixture

In this research, there are two groups of concrete mixes according to the type of exposure. Group one consists of two series have tested with compressive strength, air dry density, and flexural strength (modulus of rupture) exposed to continuous curing with water tested at age (30, 60, 90 and 120) days. Group two consists of two series have tested with compressive strength, air dry density, and flexural strength (modulus of rupture) exposed to kerosene or diesel (after curing them in water for 28 days before exposure) tested at age (60, 90 and 120) days. All the concrete mixes are designed according to **(ACI 211)** by the volume method with the target strength (30 MPa) at 28 days and the mix proportions of the concrete are given in **Table (9)**. All the concrete in this research had the same volumetric proportion of fine and coarse aggregate, and the amount of water (mix water) is kept the same in these concrete mixes, resulting in a constant W/C of (0.54) for all mixes.

Results and Discussion
Compressive strength

The result of compressive strength of concrete mixes (reference and reinforced concrete with different volume fraction of steel fiber (0.5, 0.75 and 1% by volume of concrete)) are shown in **Tables from (10) to (12)** and plotted in **Figure from (1) to (3)**.

The test results present that the compressive strength of reference concrete is increased as the time of continuous curing in water increase , this is due to continuous hydration of cement paste, then, increases the bond between cement paste and aggregate **(Shetty 2000) and (Neville 2010)**.

From the test results, it can be seen that the concrete mixes reinforced with SF is increased continuously with the time of curing in water was increase. The maximum increase was 48% when using 1% SF at 120 days as a compared at 30 days of curing.

From test results it can be seen that the compressive strength of the cubes (reference and reinforced with SF V_f (0.5, 0.75, and 1%)) mixes exposed to kerosene or diesel, at 60 days the compressive strength of them is greater than the compressive strength of the cubes (reference and reinforced with SF V_f (0.5, 0.75, and 1%)) cured in water. This is due to the pores inside the concrete which was still partially filled with water and leads to further hydration that delay the deterioration of concrete **(AL-Harby 1998)**. But at 120 days of exposure to kerosene or diesel, the compressive strength of concrete cubes (with and without SF) is decrease. The decreased in compressive strength for plain and for steel fiber reinforced concrete exposed to kerosene or diesel may be attributed to the weakening in the bond strength between cement paste and aggregate and between concrete matrix and fibers with the time of exposure. **(AL-Harby 1998) and (Francis et al., 2010)**.

Density

The result of density of concrete mixes (reference and reinforced concrete with different volume fraction of steel fiber (0.5, 0.75 and 1% by volume of concrete) are shown in **Tables from (13) to (15)** and plotted in **Figure from (4) to (6)**.

From test results it can be notice that: The specimens cured in water show an increase in density as the time of curing period increased too, this is due to continuous hydration of cement, and this is in complete comply with other researches like **(Shetty 2000)**

The density of the cubes exposed to kerosene or diesel at age 60 days (after curing them in water for 28 days) is higher than the density of those cubes curing in water for the same ages. The maximum increased when used SF 1% with rates 0.65% and 0.35% for kerosene and diesel respectively. This is due to the inside pores which were partially filled with water and let to continuous hydration of cement.

At 120 days from exposure to kerosene or diesel, the density of the specimens (with and without SF) is decreased. This happens because the harmful effect of petroleum products on the bond between aggregate and cement paste and between the SF and matrix, so this led to increase porosity and decrease the strength and density **(Matii 1976) and (AL-Harby 1998)**.
The increase or decrease in density for the reinforced cubes exposed to kerosene or diesel is higher than the density for plain concrete.

FLEXURAL STRENGTH (MODULUS OF RUPTURE)

The result of Flexural strength of concrete mixes (reference and reinforced concrete with different volume fraction of steel fiber (0.5, 0.75 and 1% by volume of concrete) are shown in Tables from (16) to (18) and plotted in Figure from (7) to (9).

The test results show that, the flexural strength is increased as the curing period with water or exposed to kerosene or diesel is increase. The largest increase happens at 120 days of curing are 32.6%, 46.8%, 54% and 57.5% for plain and reinforced concrete using SF with V_f (0.5, 0.75 and 1%) curing with water respectively.

The results show that, the flexural strength of the specimens (with and without SF) exposed to kerosene or diesel increase with the time of exposure and the maximum increase at 120 days of exposure with rates 12%, 32%, 33% and 36% and 19%, 33%, 35% and 37% for plain and reinforced concrete with SF with V_f (0.5, 0.75 and 1%) exposed to kerosene and diesel respectively. The increase in flexural strength of concrete specimens exposed to kerosene and diesel are due to closing and autogenously healing of crack and flaws in concrete due to possible volume change by effect of products. **(Matti 1976)**.

The test results also show that, the Flexural strength of specimens reinforced with SF is greater than the flexural strength of plain concrete specimens, this behavior is due to the increase in crack resistance of the composite and ability of fibers to resist forces after the concrete matrix has cracked. **(Salih et al., 2005).**

CONCLUSIONS

1. The maximum increase percentage in compressive strength for specimens reinforced with SF with V_f (0.5, 0.75, and 1%) and continuously cured in water at 120 days was 9.1, 11.9 and 18.9 respectively as compared with plain concrete.
2. The decreasing or increasing in compressive Strength for specimens reinforced with SF and exposed to kerosene or diesel is better than the plain concrete exposed to same conditions. The percentage increases in compressive strength 3.8, 6.5, and 9.3 and 8, 10.9 and 16.5% at 60 and 120 days for 0.5, 0.75, and 1% Steel Fiber content by concrete volume respectively as compared with plain concrete exposed to kerosene and the

percentage increases in compressive strength 3.9, 5.3 and 8.4% and 6.5, 10.4 and 15% at 60 and 120 days for 0.5, 0.75, and 1% Steel Fiber content by concrete volume respectively as compared to plain concrete exposed to diesel.

3. The density of reinforced specimens cured in water is increased as the percentage of SF increase and the maximum increase was 4.9% when SF 1% is used.
4. The density of the specimens exposed to kerosene or diesel at age 60 days (after curing them in water for 28 days) is higher than the density of those specimens cured in water for the same ages. The maximum increase when used SF 1% is used with rates 0.65% and 0.35% for kerosene and diesel respectively.
5. At 120 days from exposure to kerosene or diesel, the density of the specimens (with and without SF) is decreased.
6. The flexural strength of the prisms cured in water was increased as the curing period increased. The maximum increasing happen at 120 days of curing are 32.6%, 46.8%, 54% and 57.5% for plain and reinforced concrete using SF with V_f 0.5, 0.75 and 1% cured with water respectively.
7. The flexural strength of the prisms (with and without SF) exposed to kerosene or diesel increased with the time of exposure and the maximum increase was at 120 days of exposure with rates 12%, 32%, 33% and 36% and 19%, 33%, 35% and 37% for plain and reinforced concrete using SF with V_f (0.5, 0.75 and 1%) exposed to kerosene and diesel respectively.
8. Flexural strength of prisms reinforced with SF is greater than the flexural strength of plain concrete prisms cured in water or exposure to kerosene or diesel. The maximum increasing percentage in flexural strength was when used 1% SF at 120 days. The rates were 41.8%, 55.6% and 48.5% for water, kerosene and diesel respectively.

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Table (1) Physical Properties of Cement

Physical properties	**Test result**	**Limits of Iraqi spec. No. 5/1984**
Fineness (Blaine Specific surface (m^2/kg))	290	≥ 230
Time of Setting (Vicat test) Initial Set (hrs : min) Final Set (hrs : min)	1 : 48 4 :27	0 : 45 (min) 10 : 00 (max)
Compressive Strength (MPa) 3 Days 7 Days	20.6 31.8	15.00 (min) 23.00 (max)

Table (2) Chemical Analysis and Composition of Cement

Compound composition	**Percentage by weight**	**I.O.S.5: 1984: limits**
CaO	58.98	--------
SiO_2	19.74	--------
Al_2O_3	3.72	--------
Fe_2O_3	3.54	--------
SO_3	2.73	Max.2.8%
MgO	3.78	Max. 5%
Na_2O	0.22	--------
K_2O	0.67	--------
Loss On Ignition (L.O.I)	3.46	Max.4%
L.S.F	0.92	(0.66-1.02)
Insoluble Residue (I.R)	0.74	Max.1.5%
Bogue Potential Compound Composition, %		
C_3S	52.26	---------
C_2S	17.17	---------
C_3A	3.87	---------
C_4AF	10.77	---------

Table (3) Grading Analysis of Fine Aggregate.

Sieve size (mm)	**Accumulated percentage passing (%)**	**Limit of Iraqi specification**

		No. 45/1984 (Zone 1)
9.50	100	100
4.75	90	90 – 100
2.63	71	60 – 95
1.18	51	30 – 70
0.60	30	15 – 34
0.30	9	5 – 20
0.15	1.2	0 – 10

Table (4) Properties Fine Aggregate

Property	**Results**	**Iraqi specification limits I.O.S 5/1984**
Grading Zone	First	------
Fineness Modulus	2.56	------
Apparent Specific Gravity	2.58	------
Bulk Density(Kg/m^3)	1670	-----
Absorption %	3	------
Sulfate Content (SO_3) %	0.21	≤ 0.5

Table (5) Grading Analysis of Coarse Aggregates.

Sieve size mm	percentage passing (%)	Limit of Iraqi specification No. 45/1984
37.5	100	100
20	100	95-100
10	42	30-60
4.57	2.1	0-10

Table (6) Properties of Coarse Aggregate

Property	Results	Iraqi specification limits I.O.S.5/1984
Apparent Specific gravity	2.6	…………..
Absorption	0.68%	……………
Sulfate content (SO_3)	0.05%	Max. 0.1%
Finer than sieve No.200 (75 µm)	2.2%	Max. 3%
Bulk Density (kg/m^3)	1600	……………

Table (7) Properties of used Steel Fibers.

Property	Specification
Density	7860 kg/m^3
Ultimate strength	1500 MPa
Modulus of elasticity	2 *10^5 MPa
Poisson's ratio	0.28
Length	50 mm
Diameter	0.5 mm
Aspect ratio	100

Table (8) Properties of Kerosene and Diesel

Oil Inspection Data	Kerosene Results	Diesel Results
Moisture content% by volume	0%	0%
Sulfur content% by weight	0.31%	0.8%
pH	7.6	6.3
Specific gravity (gm/cm^3) at:		
20C°	0.784	0.829
25C°	0.708	0.825
30C°	0.777	0.821
35C°	0.774	0.817
40C°	0.770	0.813

Viscosity (centipoises) at:		
20C°	1.185	4.635
25C°	1.092	3.960
30C°	1.019	3.570
35C°	0.935	3.257
40C°	0.855	2.943

Table (9) The mix proportion of concrete according to ACI (211-91).

The materials	The mix proportion Kg/m^3
Water	228
Cement	422
Coarse aggregate	768
Fine aggregate	807

Table (10) Results of Compressive Strength (MPa) of Concrete Mixes cured in Water.

No.	Mixes	Age (Days)			
		30	60	90	120
1	Ref.	35.9	42.5	44.52	49.51
2	Mix.0.5	37.93	45.75	48.12	54.02
3	Mix.0.75	39.3	46.85	49.5	55.41
4	Mix.1	39.7	47.6	52.15	58.78

Table (11) Results of Compressive Strength (MPa) of Concrete Mixes exposed to Kerosene.

No.	Mixes	Age (Days)		
		60	90	120
1	Ref.	39	42	41
2	Mix.0.5	40.5	45	42.12
3	Mix.0.75	41.53	45.98	43.25
4	Mix.1	42.62	47.12	46.17

Table (12) Results of Compressive Strength (MPa) of Concrete Mixes exposed to Diesel.

No.	Mixes	Age (Days)		
		60	90	120
1	Ref.	38.45	41.43	38.87
2	Mix.0.5	39.95	43.95	40.98
3	Mix.0.75	40.5	44.85	42.5
4	Mix.1	42.65	46.25	43.76

Table (13) Results of density (kg/m^3) for concrete specimens cured in water.

No.	Mixes	Age (Days)			
		30	60	90	120
1	Ref.	2375	2417	2438	2453
2	Mix.0.5	2390	2458	2477	2519
3	Mix.0.75	2418	2471	2497	2540
4	Mix.1	2429	2495	2530	2574

Table (14) Results of density (kg/m^3) for concrete specimens exposed to kerosene.

No.	Mixes	Age (Days)		
		60	90	120
1	Ref.	2395	2412	2402
2	Mix.0.5	2420	2448	2437
3	Mix.0.75	2433	2468	2454
4	Mix.1	2445	2485	2478

Table (15) Results of density (kg/m^3) for concrete specimens exposed to diesel.

No.	Mixes	Age (Days)		
		60	90	120
1	Ref.	2389	2406	2396
2	Mix.0.5	2417	2443	2430
3	Mix.0.75	2426	2463	2440
4	Mix.1	2435	2479	2463

Table (16) Results of Flexural Strength (MPa) of Concrete Specimens Cured in Water.

No.	Mixes	Age (Days)			
		30	60	90	120
1	Ref.	2.94	3.44	3.45	3.9
2	Mix.0.5	3.35	4.21	4.5	4.92
3	Mix.0.75	3.5	4.45	4.72	5.4
4	Mix.1	3.65	4.6	4.98	5.72

Table (17) Results of Flexural Strength (MPa) of Concrete Specimens Exposed to Kerosene.

No.	Mixes	Age (Days)		
		60	90	120
1	Ref.	3.21	3.55	3.6
2	Mix.0.5	3.5	4.45	4.65
3	Mix.0.75	3.88	4.62	5.1
4	Mix.1	4.2	4.82	5.65

Table (18) Results of Flexural Strength (MPa) of Concrete Specimens Exposed to Diesel.

No.	Mixes	Age (Days)		
		60	90	120
1	Ref.	2.98	3.48	3.57
2	Mix.0.5	3.46	4.39	4.61
3	Mix.0.75	3.6	4.57	4.85
4	Mix.1	3.85	4.75	5.3

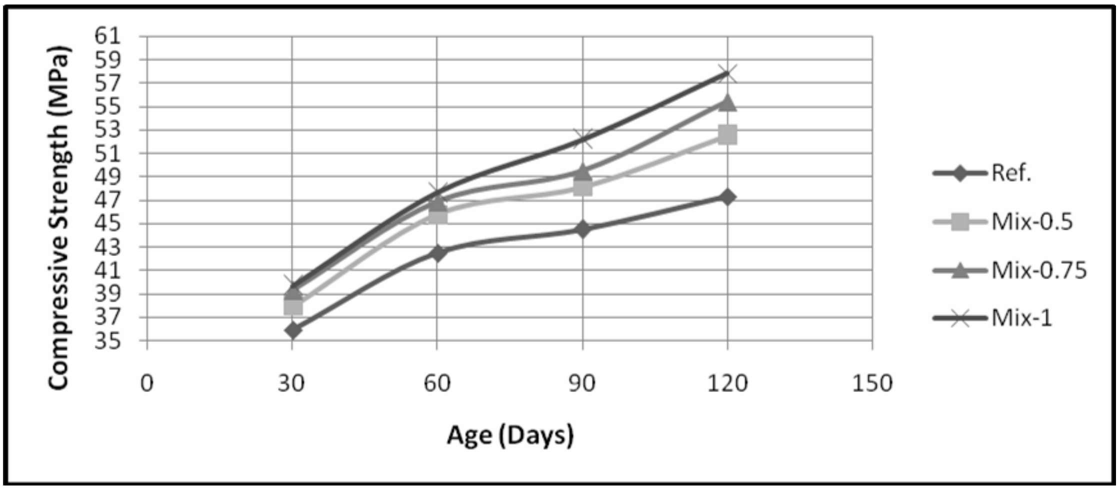

Figure (1) Effect of Steel fiber content on compressive strength of concrete cured in water.

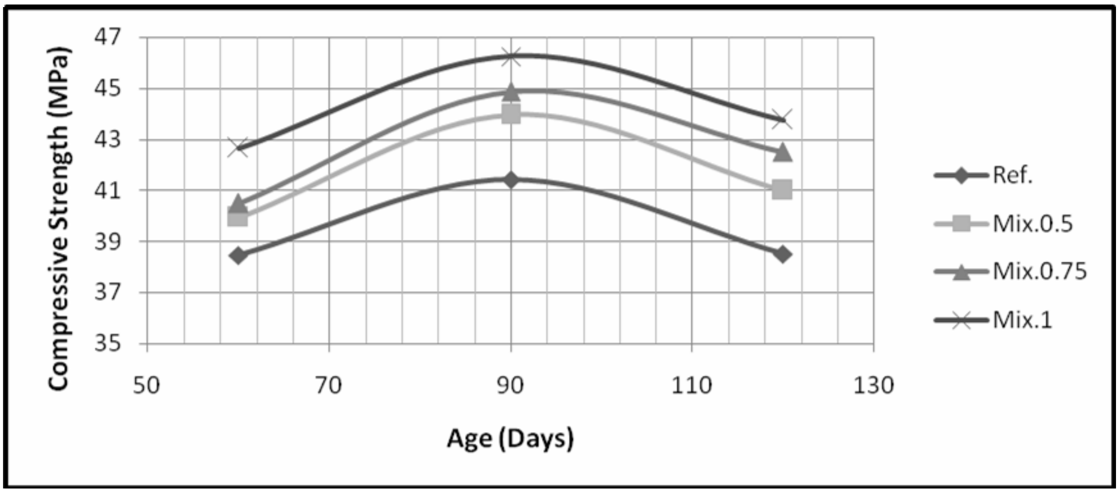

Figure (2) Effect of Steel fiber content on compressive strength of concrete exposed to Kerosene.

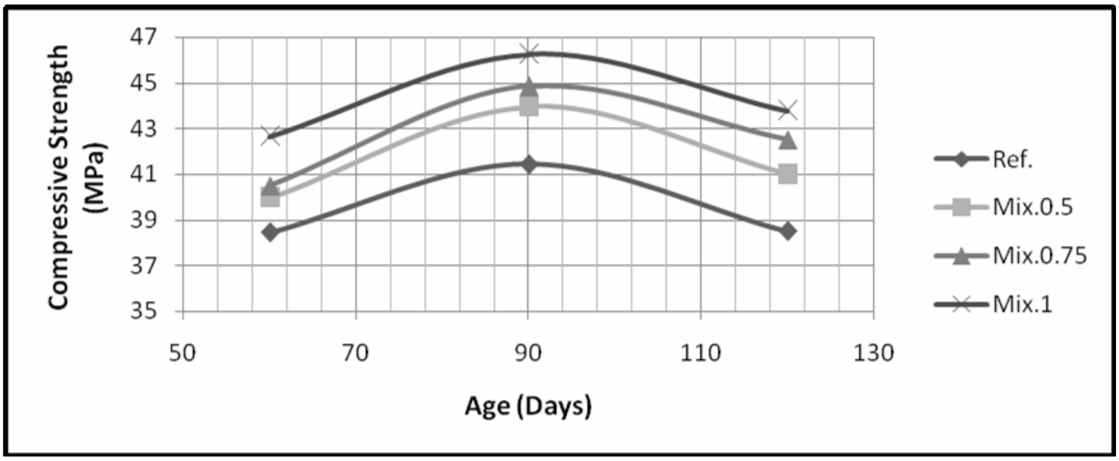

Figure (3) Effect of Steel fiber content on compressive strength of concrete exposed to Diesel.

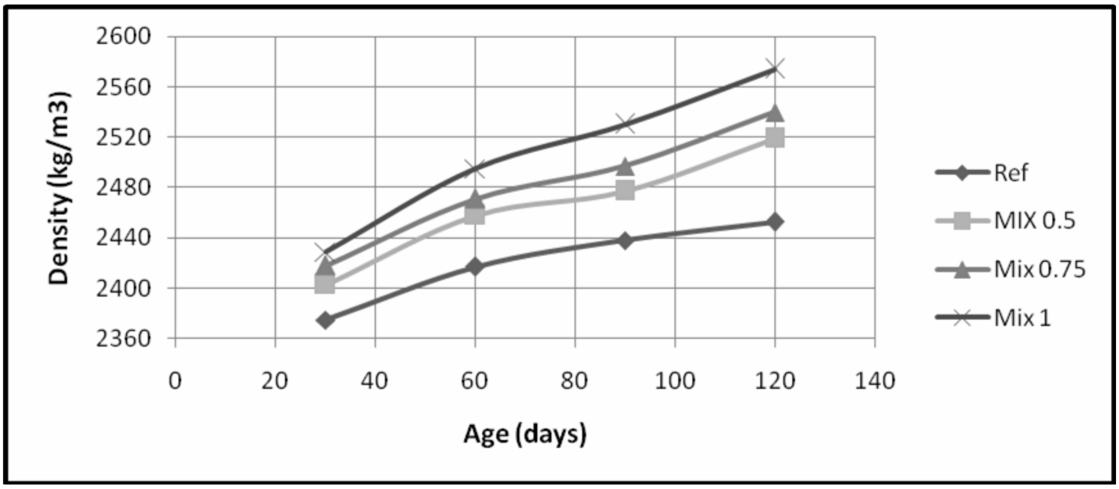

Figure (4) Effect of Steel fiber on density of concrete cured in water.

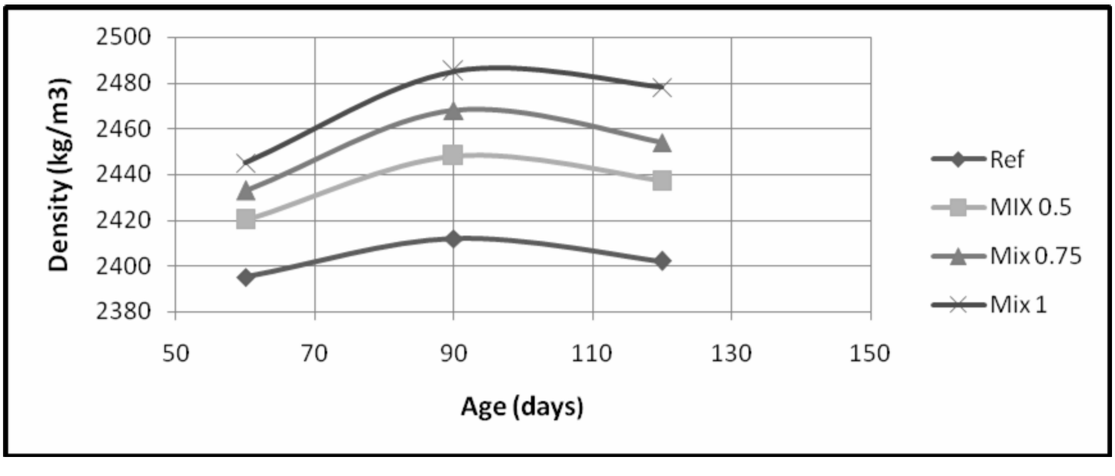

Figure (5) Effect of Steel fiber on density of concrete exposed to Kerosene.

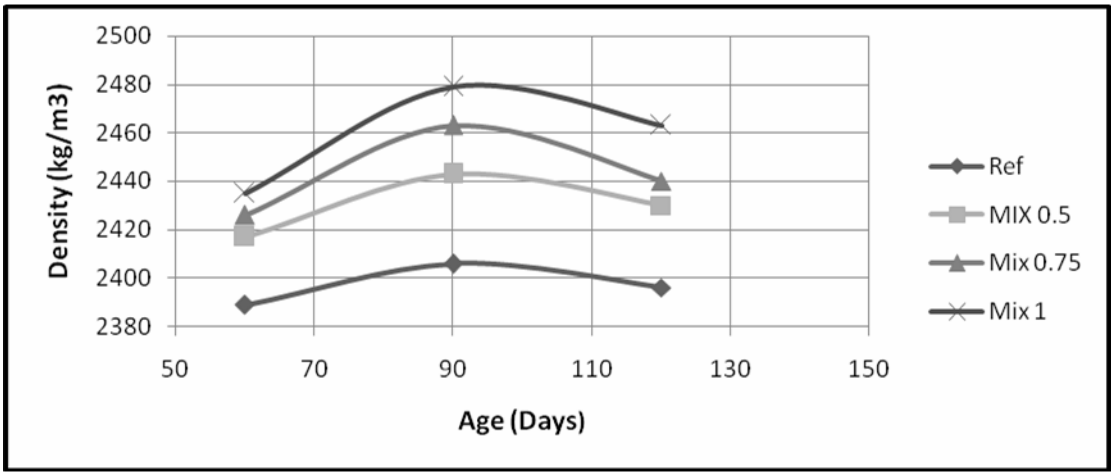

Figure (6) Effect of Steel fiber on density of concrete exposed to Diesel.

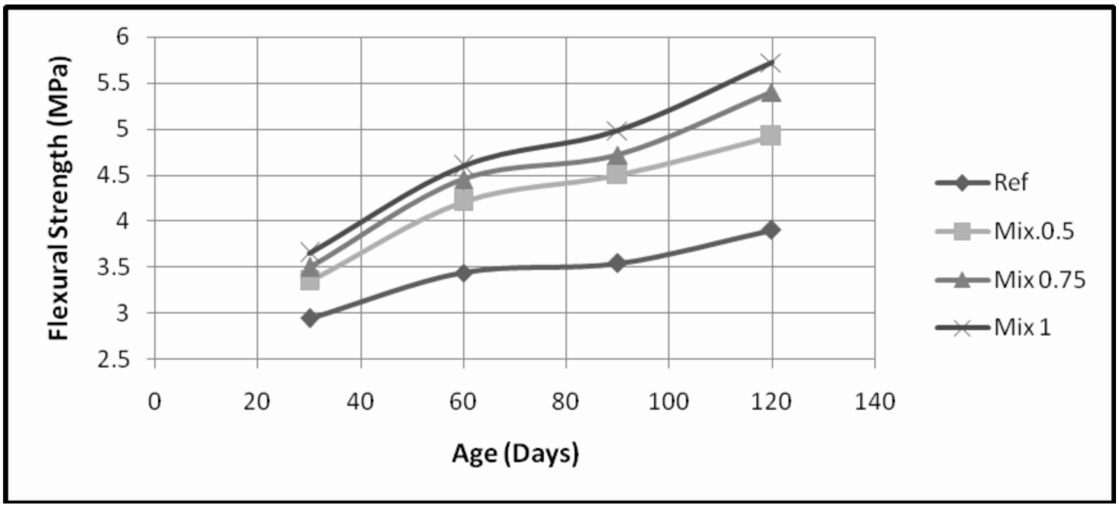

Figure (7) Effect of Steel fiber contents on Flexural Strength of concrete cured in water.

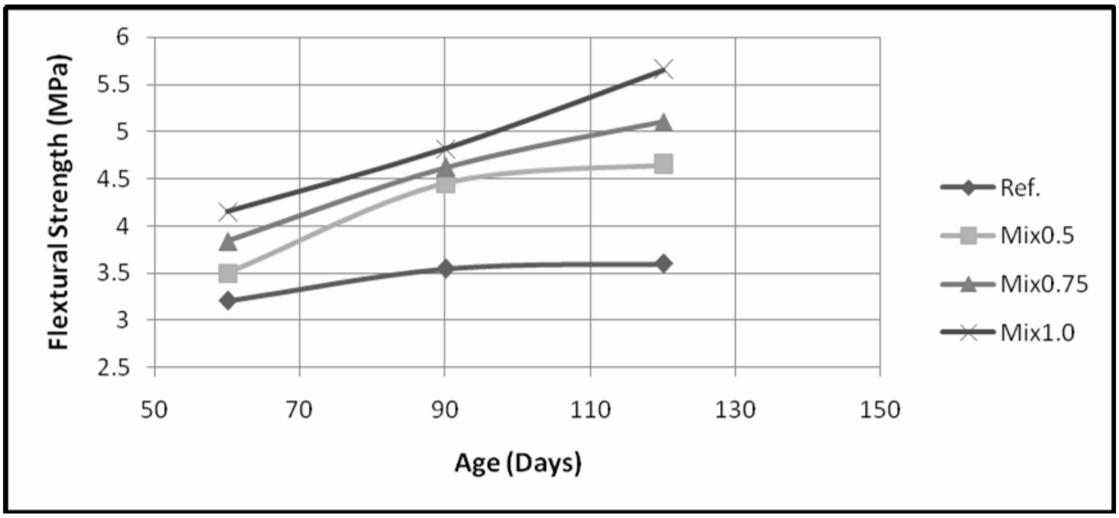

Figure (8) Effect of Steel fiber on Flexural Strength of concrete exposed to kerosene.

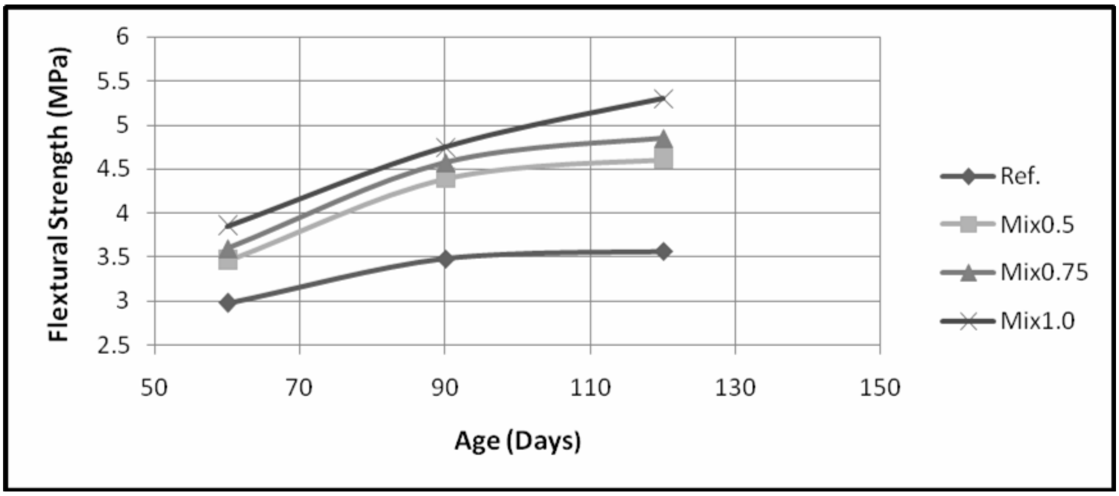

Figure (9) Effect of Steel fiber on Flexural Strength of concrete exposed to Diesel.