EFFECT OF OIL PRODUCTS ON COMPRESSIVE STRENGTH OF REACTIVE POWDER CONCRETE

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ABSTRUCT

The aim of this study is to investigate the effect of two of oil products (kerosene and fuel oil which is locally called as black oil) on compressive strength of reactive powder concrete (RPC). RPC was prepared using cement, silica fume, fine sand, steel fibers and superplasticizer to cast and test 63 specimens of cubes with various steel fibers ratios of 0%, 1% and 2% at different exposure times in oil products (0, 30, 90 and 180) days. In general the results showed that RPC has good resistance to the effect of kerosene and fuel oil. A slight decrease in compressive strength occurred as the time of exposure to the oil products increases. The RPC specimens of 2% steel fibers content had the lower decrease in compressive strength as a result of the denser microstructure. The decreasing ratio of RPC compressive strength exposed to fuel oil (1.33%) was lower than that of kerosene (2.91%). This may be attributed to the lower viscosity of kerosene than fuel oil.

KEY WORDS: reactive powder concrete, oil products, kerosene, black oil, compressive strength.

تأثيرالمشتقات النفطية على مقاومة الأنضغاط لخرسانة المساحيق الفعالة

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الخلاصة

الهدف من هذه الدراسة هو التحري عن تأثير اثنين من المشتقات النفطية (النفط الابيض و نفط الوقود المعروف محليا بالنفط الأسود) على مقاومة الأنضغاط لخرسانة المساحيق الفعالة. تم تحضير خرسانة المساحيق الفعالة من السمنت، الرمل الناعم، أبخرة السليكا, ألياف الحديد والملدن المتفوق لصب و فحص 63 نموذج من المكعبات بأستخدام نسب مختلفة من ألياف الحديد (0%، 1% و2%) عند اوقات تعرض مختلفة في المشتقات النفطية (0، 30، 90 و 180) يوم. بشكل عام النتائج اظهرت ان خرسانة المساحيق الفعالة ذات مقاومة جيدة لتأثيرالنفط الابيض و النفط الاسود. مقاومة الانضغاط انخفضت قليلا بزيادة زمن التعرض للمشتقات النفطية. الخلطة التي تحتوي على 2% الياف حديد هي الاقل انخفاضا في المقاومة كنتيجة لهيكلها الاكثر كثافة. ان نسبة الانخفاض في مقاومة الانضغاط لخرسانة المساحيق الفعالة المتعرضة لنفط الوقود (1.33%) أقل من تلك المتعرضة للنفط الابيض (2.91%). ان ذلك قد يعود للزوجة الاقل للنفط الابيض مقارنة مع نفط الوقود.

الكلمات المرشدة: خرسانة المساحيق الفعالة،المشتقات النفطية، النفط الابيض، النفط الاسود، مقاومة الانضغاط.

INTRODUCTION

In the mid 1990`s, one of the astonishing developments in the field of concrete technology was made by introduction of ultra-high performance fiber reinforced (UHP-FRC) by Richard and Cheyrezy (1994) which is more commonly known as ultra-high performance reactive powder concrete (RPC) [Behzad et al. (2012)]. Reactive powder concrete (RPC) is coarse aggregate-free concrete, which has limited applications so far recorded in the construction industry [Tam et al. (2012)].

Oil has become one of the most vital energy resources from the beginning of the previous century for its unique economic and operative characteristics. This has enabled it to exceed the other available power resources, and its importance has increased rapidly with its wide spread use and the discovery of huge oil reserves in different parts of the world [Ra'ed (2002)].

Durable concrete has the ability to withstand the effects of environmental conditions to which it will be subjected, such as weathering, chemical attack, and abrasion. The migration of water, petroleum products, and other liquids through properly designed, placed, consolidated, and uncracked concrete is minute. Concrete is impermeable for all intents and purposes. For example, with a permeability coefficient of (3×10^{-14}m/s) for concrete with a water cement ratio of 0.45, the loss of water through the wall of (1900 m^3) tank would be less than (4 litters) per year. The thickness of the concrete and the hydrostatic head of the liquid in tanks of normal proportions do not significantly affect the rate of migration through the concrete [Close and Jorgensen (1991)].

Structures for storage or transportation of oil have for years been constructed of steel, but as a result of the critical storage of steel plate and problems of serviceability and safety during the Second World War, reinforced or prestressed concrete tanks were used to store many different liquids, such as: crude oil, bitumen, heavy fuel oil, light fuel oil, gas oil, lamp kerosene, power kerosene etc. [Abdul Hussein (2005)]

Storage of liquid petroleum products may be done in above ground or underground steel or concrete tanks or in underground salt domes, mined caverns or abandoned mines. Underground tanks are most common for military bases, gasoline stations and wholesale bulk storage terminals [Cholakov (2003)].

[AL-Zaidi (2001)] Studied the influence of oil products (gas oil and kerosene) on the physical properties of concrete and he revealed that specimens cured in gas oil and kerosene showed higher compressive strength for all ages compared with their water counterparts. The effect of state of concrete (wet or dry) before exposure to oil products doesn't produce significant effect on the compressive strength.

Many researchers [Lea (1970), ACI (1968), Pearson and Smith (1919)] have reported that mineral oil has no effect on the quality of concrete. The damage of the oils depends on their viscosity; the higher viscosity of the oil, concrete is the less dangerous [Rashed (1998)]. Therefore viscosity of oil is a very important property for oil store tanks [Spamer (1994), [Biczock (1964) and Hernibrock (1994)].

Researches conducted by [Williamson (1982), Bergstrom (1975) and Jonston (1982)] showed that the increase in compressive strength was ranging from negligible, in most cases, to 15% for 150mm×300mm cylinders containing different types and contents of fibers.

[Al-Hamadani (1997)] Studied the mechanical properties of concrete exposed to gas oil. He used different types of admixture such as High Rang Water Reducing agent (HRWR), Microsilica agent (MS), Lime Stone Dust (LSD) and he found that the compressive strength of dried concrete specimens resoaked in gas oil was increased by (2.6%, 4.1%, 1.7%, and 2.4%) after 180 days soaking for HRWR, MS and LSD mix. The compressive strength of the admixture concrete was higher than that of concrete without admixture for the same curing and exposure conditions. The increase in strength of admixture concrete was attributed to the pozzolanic activity in case of using micro silica, which produced additional gel, and due to reduced w/c ratio in case of HRWR. For LSD concrete the reduction in air content and filler increase in density were responsible for the observed increase in strength.

The following advantages and disadvantages of concrete for oil storage can be listed [Abdul-Hussain (2005)].

- **Advantages:-**
  1. Much lower cost compared with steel plates.
  2. The availability of its raw materials throughout the world.
  3. A significant durability towards different types of environment.
  4. Good resistance to fire, explosions and impact.
  5. Its adaptability for different types.
  6. Relative low maintenance cost.
  7. Its suitability for underground, and under-sea storage tank.
- **Disadvantages:-**

1. The unknown behavior of concrete in direct contact with oil products.
2. Penetration of the lighter fraction of oil products through the tanks.
3. Concrete undergoes volume changes. These may be as shrinkage or thermal movements. Thus cracking may be unavoidable.
4. Possible bond weakening in oil saturated concrete tanks.
5. The impossibility of moving concrete tanks to different locations.
6. Possibility of cracks due to differential settlement.

The present work is focused on compressive strength of RPC after exposure to oil products because of the most common of all tests on hardened concrete is the compressive strength test, partly because it is an easy test to perform, and partly because many, though not all, of the desirable characteristics of concrete are qualitatively related to its strength; but mainly because of the intrinsic importance of the compressive strength of concrete in structural design [Neville (2005)].

EXPEREMENTAL PROGRAM

The experimental program was conducted to study the behavior of concrete mixes of RPC that was in direct content with oil products. The purpose of this investigation is to identify the means of achieving impermeable concrete that can be used for the construction of oil storage tanks or oil pipelines. There are many other industrial situations where concrete may come into direct contact with different garage floor and oil drilling rings… etc.

The specimens were exposed to oil products for various times after water curing of 28 days and compared with reference mix specimens which was cured in water without exposure to oil products. Two types of oil products have been used (kerosene and fuel oil). The exposure time to the oil products were (0, 30, 90 and 180) days after the initial curing.

MATERIALS

CEMENT

Ordinary Portland cement (type I Tasluja-Bazian) which is produced in Iraq by the United Cement Company (UCC) was used in all test specimens. The chemical analysis and physical test results of the cement are given in (**Tables 1 & 2)**, respectively. They conform to the [Iraqi specification No. 5/1984].

SILICAFUME

Silica fume is a highly reactive material that is used in relatively small amounts to enhance the properties of concrete. The chemical composition and properties of silica fume used in this work are given in (**Table 3)**.

STEEL FIBERS

The characteristics of steel fibers used in the experimental program are given in (**Table 4). (Figure 1)** shows a sample of the used steel fibers.

FINE AGGREGATE

Fine aggregate from Al-najaf Al-ashraf region has been used. It is yellowish brown colored sand with rounded shaped particles. The grading of this sand is shown in (**Table 5)**.

SUPERPLASTICIZER

A superplasticizer type which is known commercially as (SikaVisco Crete-PC 20) was used in this work. SikaViscoCrete-PC 20 is a third generation superplasticizer for concrete and mortar. (**Table 6)** indicates the technical description of aqueous solution of the superplasticizer used. It is free from chlorides and complies with [ASTM C494/C494M-1999a].

OIL PRODUCTS

(Table 7) show the properties of kerosene and fuel oil respectively which are used in this investigation. They were brought from the local market and stored in plastic containers to avoid any losses.

Water

Tap water has been used for concrete mixing and curing of specimens.

MIX PROPORTIONS

In most basic form, reactive powder concrete contains high content of Portland cement as main cementitious materials beside silica fume as a second supplementary cementitious component. The superplasticizer has been used in an appropriate ratio to give flowable concrete. In addition steel fibers are also added to enhance its properties. Many mix proportions were tried in this study to get maximum compressive strength. The variable used in the RPC mix was the volume ratio of steel fibers (three volume ratios were considered 0%, 1% and 2%). The mix proportions of RPCṡ are shown in (**Table 8)**.

MIXING PROCEDURES

Mixing procedure proposed by [Wille et al (2011)] was used in this research to obtain RPC in a simpler way without any accelerated curing regimes. Pan mixer of 0.056 m^3 capacity was used to prepare the concrete. Sand and silica fume were first mixed for 4 minutes, then cement was added and the dry component (cement, sand and silica fume) were mixed for 5 minutes. Superplastcizer was added to the water and stirred, then the blended liquid was added to the dry mix during the mixer rotation and the mixing process continues for 3 minutes. Finely, steel fibers were all added by hand within 2 minutes. The total mixing time was about 14 minutes.

SPECIMEN'S PREPARATION AND CASTING PROCDURE

Specimen's molds (50 mm cubes) were cleaned thoroughly, tightened well and the internal surfaces were oiled with thin car engine oil to prevent the hardened Concrete adhesion with molds. Once the concrete mixing was done, the molds were filled with RPC. A vibrating table was used for consolidation of RPC into the molds. After being molded, all the specimens were cured under polyethylene sheets for about 24 hr in a laboratory environment.

CURING

After 24 hours of casting, the specimens were stripped from molds and placed in water containers in the laboratory to be cured at room temperature. Heat curing at elevated temperature was not used in this research in order to gain an advantage of producing RPC of exceptional mechanical properties using conventional curing method without any additional provisions. After 28 days of water curing, the specimens were soaked in kerosene or fuel oil in plastic containers for different exposure times (30, 90 and 180 days) until test date. Reference specimens (o day exposure time) where tested immediately after the end of water curing.

TEST RESULTS

Three cubes of (50mm×50mm×50mm) for each mix were tested to determine the compressive strength and an average value is obtained according to [ASTM C109/C109 (2002)]. Compressive strength test was performed by using universal testing machine (ELE) of 2000 KN capacity in the Constructional Materials Laboratory of Engineering College of Al-Mustansyiria University. Results are given in (**Table 9)** and presented in (**Figures 2 & 15)**.

(Figures 2 & 3) show the relationship between compressive strength and different exposure times of kerosene and fuel oil. Generally, it is shown from these Figures that a slight decrease in compressive strength occurred as the time of exposure increases for the specimens exposed to kerosene and fuel oil. It is also shown that compressive strength of RPC increases with the increase in steel fibers ratio.

(Figures 4 & 5) show the relationship between compressive strength and steel fibers ratio of various exposure times of kerosene and fuel oil respectively. It is shown from these figures that the compressive strength increases with the increase of steel fibers ratio. At the ratio of 2% steel fibers the decrease in compressive strength after exposure time 180 days is slight compared with the mixes of 0% and 1% steel fibers content for both kerosene and fuel oil exposure.

(Figures 6 to 8) show the relationship between compressive strength and steel fibers ratios at exposure time (30, 90 and 180) days, respectively. It is shown from these figures that RPC exhibits good resistance to kerosene and fuel oil exposure especially the mixes with 2% steel fibers. As mentioned before. These best results obtained from RPC with 2% steel fibers may be attributed to its more dense microstructure compared to RPC with lower steel fibers ratios.

(Figures 9 to 11) show the relationship between compressive strength and exposure time for mixes of (0%, 1% and 2% steel fibers) respectively. These figures show that the compressive strength of specimens exposed to fuel oil is slightly higher than that of specimens exposed to kerosene at the same exposure time and steel fibers ratio. This may be attributed to the lower viscosity of kerosene than of fuel oil **(see Table 7)**, which enable kerosene to penetrate through concrete easier than fuel oil.

(Figures 12 & 13) show the decreasing ratio in compressive strength of RPC exposed to kerosene and fuel oil respectively with the increase in exposure time. Generally, low decrease in compressive strength of RPC exposed to kerosene and fuel oil was observed. It is shown in these figures that the decreasing ratio in compressive strength is reduced with addition of 1% steel fibers as presented in **(Table 9)**. This reduction is greatly enhanced when 2% steel fibers used. For example, the addition of 1% steel fibers reduces the decreasing ratio in compressive strength from 10.14% to 9.46% for RPC exposed to kerosene for 180 days. The addition of 2% steel fibers drops this ratio to 2.91%. Similar trends for other exposure times are shown in **(Figures 12 & 13)** and can be read from the results listed in (**Table 9)**.

These results makes steel fibers ratio of 2% to be the more effective ratio to enhance the permeability of RPC through the enhancement in RPC microstructure in addition to the main role of steel fibers in increasing ductility and tensile strength of RPC. However, lower decreasing ratios were recorded for RPC exposure to fuel oil (only 1.33 % after 180 days of exposure for RPC with 2% steel fibers) compared to those of RPC exposure to kerosene. This again can be attributed to the lower viscosity of kerosene.

(**Figures 12 & 13)** also show that the decreasing ratio in compressive strength increasing with the increase in exposure times for both kerosene and fuel oil. This is expected because longer exposure time allows more penetration of oil products. However, decreasing ratios (after 180 days of exposure) are ranged from 10.14% for RPC with 0% steel fibers exposed to kerosene to only 1.33% for RPC with 2% steel fibers ratio exposed to fuel oil. Lower ratios are recorded for exposure times of 30 and 90 days **(Table 9)**.The above discussion indicates the good permeability and resistance of RPC to the effects of oil products.

(Figures 14 & 15) show the increasing ratio of compressive strength of RPC exposed to kerosene and fuel oil respectively with the increase in steel fibers ratio. This increasing ratio is generally ranged from 14.38% to 21.4% where steel fibers ratio increases from 0% to 2%.

CONCLUSIONS

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

1. It is possible to produce reactive powder concrete with compressive strength of 114 MPa using normal water curing at room temperature without using heat curing.

2. For the RPC specimens exposed to kerosene and fuel oil, a slight decrease in compressive strength occurred as the time of exposure increases. The decreasing ratio is ranged from only 0.08% for RPC of 2% steel fibers exposed to fuel oil for 30 days to 10.14% for RPC of 0% steel fibers exposed to kerosene for 180 days.

3. The compressive strength of RPC increases with the increase of steel fibers ratio for different exposure times and oil products. The increasing ratio is generally ranged from 14.38% to 21.41% when steel fibers ratio increases from 0% to 2%.

4. RPC with 2% steel fibers exhibits better resistance to kerosene and fuel oil exposure (strength decreases after 180 days of exposure by 1.33% for fuel oil and 2.91% for kerosene), than that of RPC with 0% (strength decreases after 180 days of exposure by 9.42% for fuel oil and 10.14% for kerosene) and 1% (strength decreases after 180 days of exposure by 8.42% for fuel oil and 9.46% for kerosene). These better results may be attributed to the denser microstructure (lower permeability) of RPC with 2% steel fibers compared to RPC with lower steel fibers ratios.

5. The compressive strength of RPC specimens exposed to fuel oil is slightly higher than that of specimens exposed to kerosene at the same exposure time and steel fibers ratio. This may be attributed to the lower viscosity of kerosene than that of fuel oil, which enables kerosene to penetrate through concrete easier than fuel oil.

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Table (1): Chemical composition of cement*

Compound Composition	Chemical Composition	Percent by weight	[Iraqi specification No. 5/1984]
Lime	CaO	61.19	-
Silica	SiO_2	21.44	-
Alumina	Al_2O_3	4.51	-
Iron Oxide	Fe_2O_3	3.68	-
Magnesia	MgO	2.31	Maximum 5
Sulfate	SO_3	2.7	Maximum 2.8
Loss on ignition	L.O.I	2.39	Maximum 4.0
Insoluble residue	I.R	1.18	Maximum 1.5
Lime saturation factor	L.S.F	0.87	0.66-1.02
Tricalcium aluminates	C_3A	6.06	-
Tricalcium silicate	C_3S	42.85	-
Dicalcium silicate	C_2S	29.4	-
Tricalcium alumina ferrite	C_4AF	11.18	-

*All tests were made at the National Center for Construction Laboratories and research.

Table (2): Physical composition of cement*

Physical Properties	Test Results	Iraqi specification No. 5/1984
Fineness using Blain air permeability apparatus(cm^2/gm)	4050	Minimum 2300
Setting time using Vicat's instruments Initial(min.) Final(hr)	 135 3:25	 Minimum 45 Maximum 10
Compressive strength for cement Paste Cube at: 3days(MPa) 7days(MPa) 28days(MPa)	 24.4 32.3 47.2	 Minimum 15 Minimum 23

*All tests were made at the National Center for Construction Laboratories and research.

Table (3): Composition and Properties of Silica Fume*

Composition (%)	Silica fume	ASTM C1240-03
SiO_2	98.87	Minimum 85%
Al_2O_3	0.01	-
Fe_2O_3	0.01	-
CaO	0.23	-
MgO	0.01	-
K_2O	0.08	-
Na_2O	0.00	-
Blaine fineness (m^2/kg)	200000	-

*According to the manufacturer editors.

Table (4): Characteristics of steel fiber used*

Type of steel	Hooked
Relative Density	7860 kg/m^3
Yield strength	1130 MPa
Modulus of Elasticity	200 000 MPa
Strain at proportion limit	$5650*10^{-6}$
Poisson's ratio	0.28
Average length (L)	30 mm
Nominal diameter (d)	0.375
Aspect Ratio(L/d)	80

*According to the manufacturer editors

Table (5): Grading of Fine Sand*

Sieve size (mm)	Cumulative passing %	[Iraqi Specification No.45/1984] Zone 4
9.5	100	100
4.75	100	100-95
2.36	100	95-100
1.18	100	90-100
0.600	88	80-100
0.300	20	15-50
0.150	5	0-15

*The test has been performed in the Structural Material Laboratory of Engineering College of Al- Mustansyiria University.

Table (6): Technical description of the used superplasticizer*

Main action	Concrete superplasticizer
Appearance/Colures	Light brownish liquid
Chemical base	Modified polycarboxylates based polymer
Density	1.09 kg/l, at 20 °C
PH	7
Chloride ion content%	Free
Effect on setting	Non-retarding

*According to the manufacturer editors.

Table (7): Properties of oil product used*

Oil Inspection Data	**Kerosene Results**	**Fuel Oil (Black Oil) Results**
Moisture content, % by volume	0.05 - 0.1	0.05 - 0.1
Sulfer content, % by weight	0.2 - 0.3	4 - 5
H_2S Concentration ppm	2 – 3	2 - 3
Specific gravity (gm/cm^3) at: 20 C°	0.78-0.80	0.95 - 0.985
25 C°	=	=
30 C°	=	=
35 C°	=	=
40 C°	=	=
80 C°	=	=
Viscosity (centipoises)	1.36 at (20 C°)	135 at (60 C°)
	1.25 at (25 C°)	80 at (70 C°)
	1.16 at (30 C°)	63 at (75 C°)
	1.07 at (35 C°)	51 at (80 C°)
	1.00 at (40 C°)	42 at (85 C°)
	-	34 at (90 C°)
	-	29 at (95 C°)
	-	24 at (100 C°)

*Oil analyses were made by the Laboratory Department/ Al-Dura Refinery.

Table (8): Mix proportions of reactive powder concrete mixes

Mixture description	RPC 0%	RPC 1%	RPC 2%
Portland cement (C) (kg/m^3)	900	900	900
Silica fume (SF) (kg/m^3)	225	225	225
*Silica fume %	25	25	25
Fine sand (FS) (kg/m^3)	900	900	900
Steel fibers (kg/m^3)	0	78	156
**Steel fiber % (by volume)	0	1	2
Superplasticizer (Kg/m^3)	56.25	56.25	56.25
***Superplasticizer %	5.5	5.5	5.5
Water (W) (kg/m^3)	180	180	180
W/C	0.2	0.2	0.2
W/(C+SF)	0.16	0.16	0.16

***Percent of cement weight, **Percent of mix volume, ***Percent of binder (cement + silica fume) weight.

Table (9): Results of compressive strength

Mix Description	**Steel Fibers ratio (%)**	**Oil Products**	**Exposure Time (Day)**	**Compressive Strength (MPa)**	**Decreasing rate in compressive strength as time of exposure increased for the same product and steel fibers ratio (%)**	**Increasing rate in compressive strength as the steel fibers ratio increased for the same product exposure time (%)**
RPC-0%	**0**	**-**	**-**	**97.6**	**-**	**-**
A1-0%	**0**	**Kerosene**	**30**	**93.6**	**4.09**	**-**
A3-0%	**0**	**Kerosene**	**90**	**90.69**	**7.07**	**-**
A6-0%	**0**	**Kerosene**	**180**	**87.7**	**10.14**	**-**
B1-0%	**0**	**Fuel Oil**	**30**	**94.1**	**3.58**	**-**
B3-0%	**0**	**Fuel Oil**	**90**	**91.7**	**6.04**	**-**

B6-0%	**0**	**Fuel Oil**	**180**	**88.4**	**9.42**	**-**
RPC-1%	**1**	**-**	**-**	**105.6**	**-**	**7.57**
A1-1%	**1**	**Kero sene**	**30**	**101.6**	**3.78**	**7.87**
A3-1%	**1**	**Kero sene**	**90**	**98.9**	**6.34**	**8.3**
A6-1%	**1**	**Kero sene**	**180**	**95.6**	**9.46**	**8.26**
B1-1%	**1**	**Fuel Oil**	**30**	**102.8**	**2.65**	**8.46**
B3-1%	**1**	**Fuel Oil**	**90**	**99.5**	**5.77**	**7.83**
B6-1%	**1**	**Fuel Oil**	**180**	**96.7**	**8.42**	**8.58**
RPC-2%	**2**	**-**	**-**	**114**	**-**	**14.38**
A1-2%	**2**	**Kero sene**	**30**	**113.8**	**0.17**	**17.75**
A3-2%	**2**	**Kero sene**	**90**	**112.2**	**1.57**	**19.17**
A6-2%	**2**	**Kero sene**	**180**	**110.68**	**2.91**	**20.76**
B1-2%	**2**	**Fuel Oil**	**30**	**113.9**	**0.08**	**17.38**
B3-2%	**2**	**Fuel Oil**	**90**	**113**	**0.87**	**18.84**
B6-2%	**2**	**Fuel Oil**	**180**	**112.48**	**1.33**	**21.4**

Figure (1): Steel Fibers used in RPC

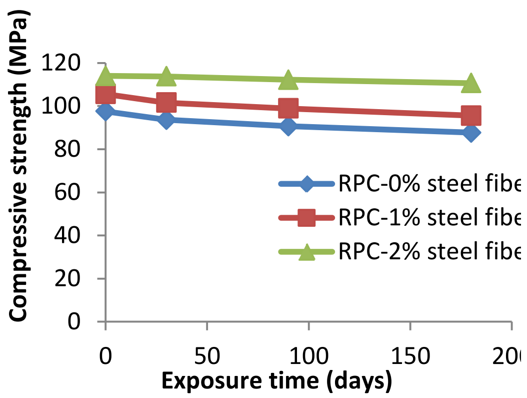

Figure (2): Relationship between compressive strength and different times of kerosen exposure

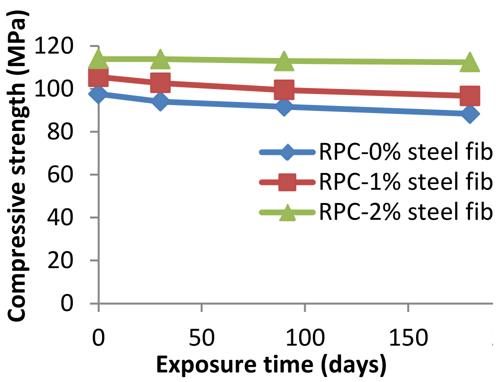

Figure (3): Relationship between compressive strength and different times of fuel oil exposure

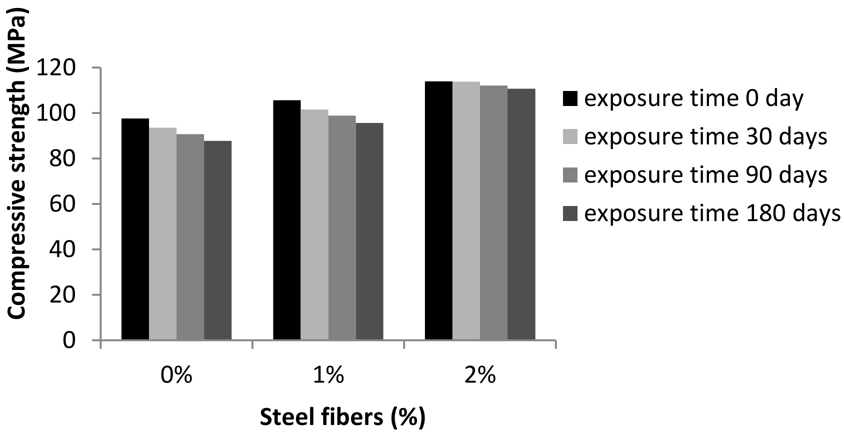

Figure (4): Relationship between compressive strength and steel fibers ratios of kerosen exposure

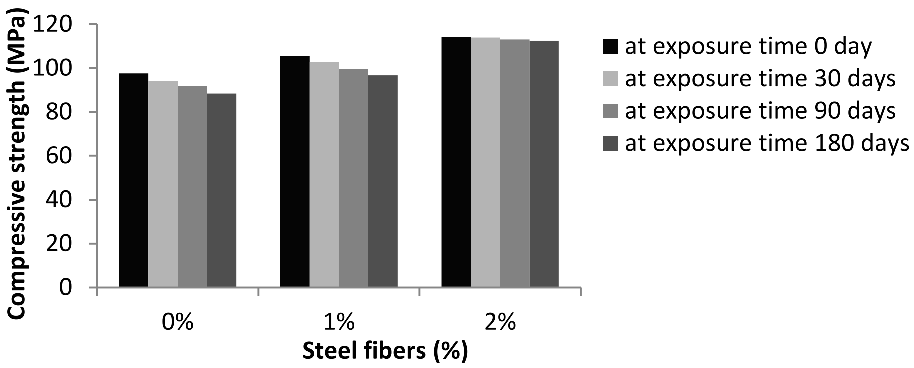

Figure (5): Relationship between compressive strength and steel fibers ratios of fuel oil exposure

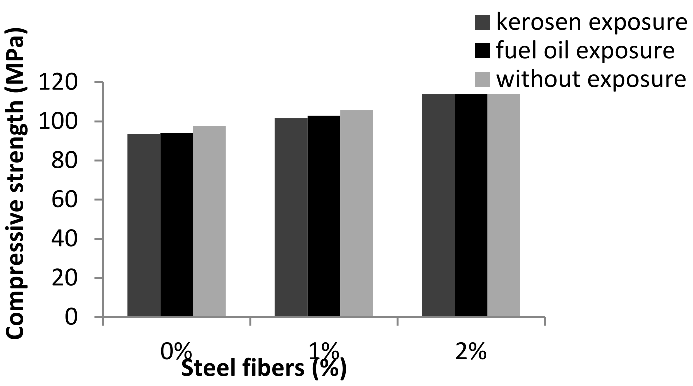

Figure (6): Relationship between compressive strength and steel fibers ratios at (exposure time 30 days) compared with mixes not exposed to oil products

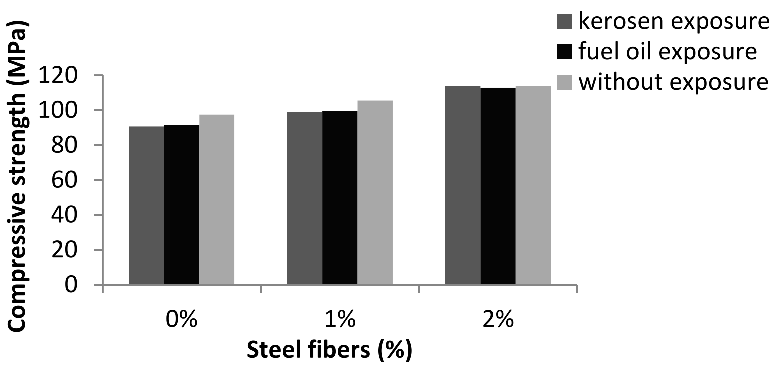

Figure (7): Relationship between compressive strength and steel fibers ratios at (exposure time 90 days) compared with mixes not exposed to oil products

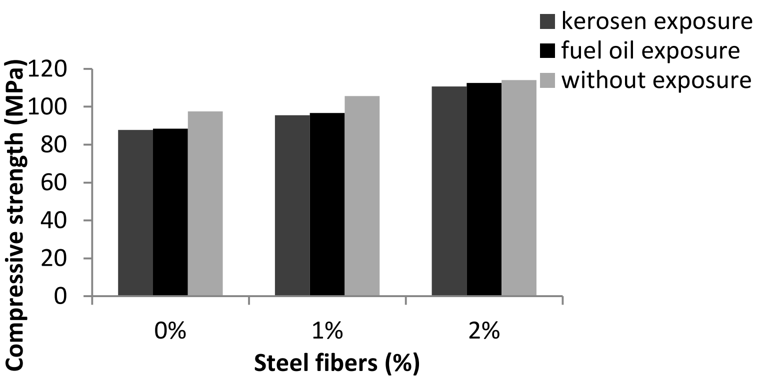

Figure (8): Relationship between compressive strength and steel fibers ratios at (exposure time 180 days) compared with mixes not exposed to oil products

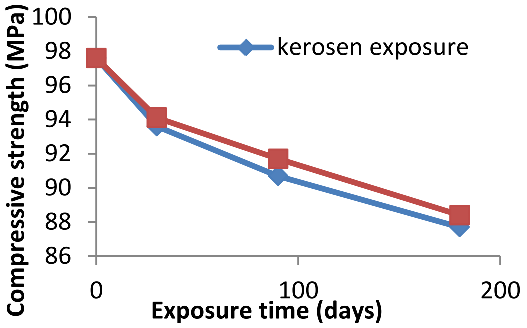

Figure (9): Relationship between compressive strength and exposure time for mixes of (0% steel fibers)

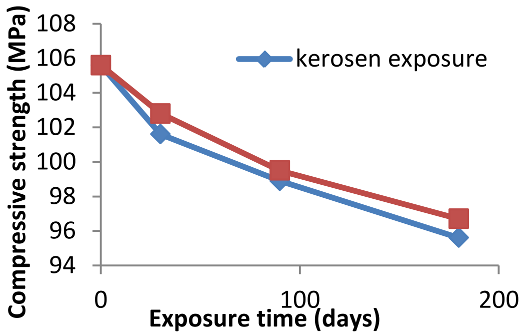

Figure (10): Relationship between compressive strength and exposure time for mixes of (1% steel fibers)

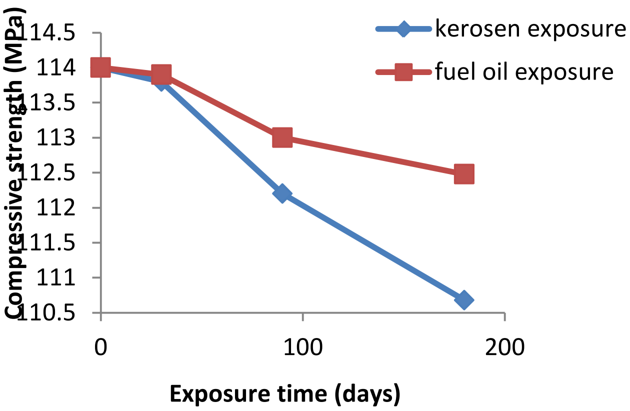

Figure (11): Relationship between compressive strength and exposure time for mixes of (2% steel fibers)

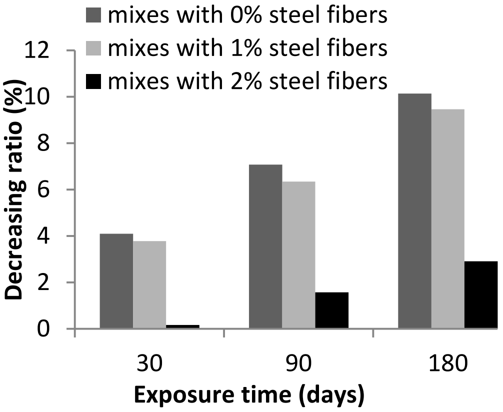

Figure (12): Decreasing ratio of compressive strength of RPC exposed to kerosen

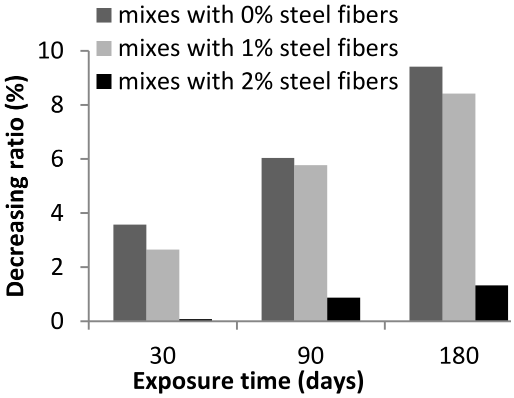

Figure (13): Decreasing ratio of compressive strength of RPC exposedto fuel oil

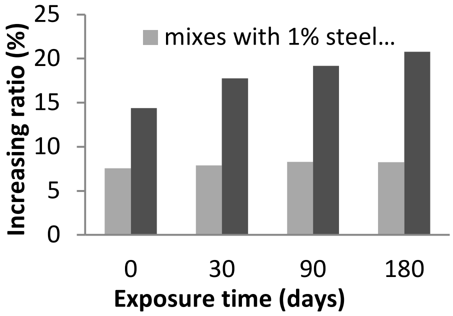

Figure (14): Increasing ratio of compressive strength of RPC exposed to kerosen

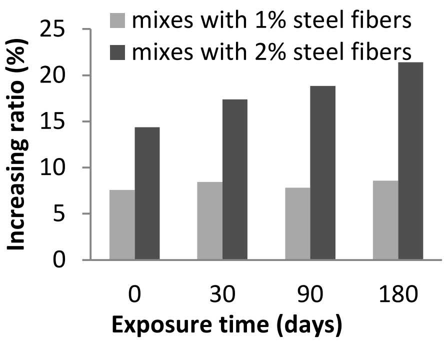

Figure (15): Increasing ratio of compressive strength of RPC exposed to fuel oil