EFFECT OF OIL ON STRENGTH OF NORMAL AND HIGH PERFORMANC CONCRETE

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Abstract:

The main objective of this investigation is to study the effect of oil (kerosene, gas oil and crude oil) on the compressive and tensile strengths of high performance concrete and to compare the behavior with that of normal strength concrete. Four exposure periods were used for each specimen and for each liquid, 30, 60, 90 and 120 days after 28 days water curing. To provide a basis for comparison, reference specimens were cast and exposed to water for a respective time of test.

The test results showed that the loss in mechanical properties (compressive and splitting tensile strengths) resulting from exposure to oil was relatively smaller for high performance concrete (HPC) compared with normal strength concrete (NSC). The difference was about 10 percent. Furthermore, the reduction in compressive and splitting tensile strengths of NSC and HPC increased with decrease in viscosity of oil in the entire period of exposure.

Keywords: High Performance Concrete, Normal Strength Concrete, Compressive Strength, Splitting Tensile Strength, Kerosene, Gas Oil, Crude Oil.

تأثير البترول على مقاومة الخرسانة الاعتيادية والعالية الاداء

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الخلاصة:

إن استخدام صفائح الحديد في خزن البترول قد اكتنفته العديد من المشاكل وبالأخص الأداء الخدمي والأمان, الأمر الذي شجع على الاستعمال الكبير للخرسانة المسلحة أو مسبقة الجهد لحماية و خزن و نقل المشتقات النفطية إن الهدف الرئيسي من هذا البحث هو دراسة تأثير البترول (النفط الأبيض, زيت الغاز والنفط الخام) على مقاومة الانضغاط والشد الانشطاري للخرسانة عالية الأداء ومقارنة سلوك هذه الخرسانة مع سلوك الخرسانة الاعتيادية.

بعد 28 يوم من المعالجة الرطبة والتجفيف بالفرن, عرضت كل النماذج الخرسانية للنفط الأبيض, زيت الغاز والنفط الخام لفترات 30, 60, 90 و 120 يوم . أما النماذج المرجعية فقد تم إنضاجها بالماء لحين إجراء الفحص.

أشارت نتائج الفحص بان الفقدان في مقاومة الانضغاط والشد الانشطاري الناتج من التعرض للبترول كان اقل نسبيا للخرسانة عالية الأداء مقارنة مع الخرسانة الاعتيادية. الاختلاف كان تقريبا 10 %. إضافة إلى ذلك إن الانخفاض في مقاومة الانضغاط والشد الانشطاري للخرسانة عالية الأداء والخرسانة الاعتيادية ازداد بنقصان لزوجة البترول خلال كل فترات التعرض.

Introduction:

As a results of the critical shortage of steel plate and problems of serviceability and safe, large concrete structures, reinforced or pre-stressed, are being built for the production, storage and transportation of oil.

Reinforced concrete tanks constructed in the past have performed satisfactorily under many various conditions and their advantages include shock and fire resistance, cheap maintenance and the fact that they may be built to much longer dimensions than steel tanks. However, concrete tanks have some disadvantages, such as the unknown behavior of concrete in direct contact with hydrocarbons, leakage or contamination of the liquid, construction difficulties due to the need to prevent differential settlement and finally the difficult of any modifications and repairs. There is a difference in the behavior of the petroleum storage concrete tanks and the water storage concrete tanks. **Matti (1976)** confirmed that leakage from concrete may be reduced with time due to enclosure of some of the voids, disconnection of the capillary channels and healing of some of the cracks due to the continuous hydration, and or accumulation of impurities. Because of the inert nature of petroleum towards concrete, such continued hydration is less likely to occur in concrete petroleum tanks, but the wax deposits that are found in crude oil may decrease the permeability of concrete .

This study will discuss the suitability of high performance concrete (HPC) in the field of oil retaining structures, like storage tanks, pavement of airports, highways and other floors that may be exposed to oil products.

Objective:

The main objective of this investigation is to study the effect of oil (kerosene, gas oil and crude oil) on the compressive and tensile strengths of high performance concrete and to compare the behavior with that of conventional concrete.

Experimental Program:

1 Materials:

1.1 Cement:

Ordinary Portland cement manufactured by Yamama Cement Factory was used in all mixes throughout this study. The percentage oxide composition and physical properties of the cement indicated that the adopted cement conforms to the **Iraqi specification No.5 /1984.**

1.2 Fine Aggregate:

Normal weight natural sand from Al-Ukhaidher region was used as fine aggregate in this work. The used sand was within zone II according to the requirements of the **Iraqi specification No.45/1984**. The specific gravity of the fine aggregate, absorption, and sulfate content (as SO_3) were 2.61, 1.7%, and 0.09% respectively.

1.3 Coarse Aggregate:

Natural crushed gravel of a maximum size 12.5 mm from Al-Nebaey region was used in this work .The specific gravity of the coarse aggregate, absorption and sulfate content (as SO_3) were (2.63), (0.6%) and (0.06%) respectively.

1.4 Admixture:

1.4.1 High Range Water Reducing Admixture (HRWRA):

A high performance concrete superplasticizer based on modified polycarboxylic ether which is known commercially (GLENIUM 51) was used throughout this investigation as a (HRWRA). It is a third generation of superplasticizers and it complies with **ASTM 494-2003** Type A and F.

Table (1) indicates the technical description of the aqueous solution of superplasticizer used throughout this study.

1.4.2 Condensed Silica Fume (CSF):

Silica fume MS-90 was used in this study. The relative density and surface area of silica fume were 2.12 and 18000 m^2/kg respectively.

1.5 Oil

Three types of oil products were used in this study, kerosene, gas oil and crude oil products. The oil were brought from Al-Najaf station and stored in air tight steel containers to avoid losses and contamination. **Table (2)** shows the viscosity of oil used.

2 Mixture Proportions:

Specimens were made from two type of concrete, the first was normal strength concrete (NSC) and the other was high performance concrete (HPC). The details of the two concrete mixes used throughout this investigation are shown in **Table (3).**

3 Preparation and exposure of specimens

After were demoulded, the specimens were cured in tap water at laboratory temperature up to the age of 28 days. After that they were dried in oven at 75 ^oC until reaching almost a constant weight

Four exposure periods were used for each specimen and for each liquid (kerosene, gas oil crude oil, and water as reference). These periods were 30, 60, 90 and 120 days after 28 days water curing. To provide a basis for comparison, reference specimens were cast and exposed to water for a respective time of test.

4 Tests:

4.1 Compressive Strength:

The compressive strength test was determined according to B.S. 1881 Part 116. This test was conducted on 150 mm cubes using an electrical testing machine with a capacity of 2000 kN at loading rate of 15 MPa per minute.

4.2 Splitting Tensile Strength:

The splitting tensile strength test was performed according to ASTM C496, (2003). (d=150 mm, h=300 mm) concrete cylinders were used. The specimens were tested using an electrical testing machine with a capacity of 2000 kN.

Results and Discussion:

1 Compressive strength:

The test results for compressive strength of NSC and HPC exposed to different oils up to age of 120 days exposure are given in **Table (4)** and the change in compressive strength due to oil products compared with water strength are plotted in **Figures (1) and (2).**

The results shown in **Figures (1) and (2)** indicate that the specimens which were kept continuously cured in water after demoulded and tested in a saturated surface dry condition, showed a continuous increase in compressive strength with age. After 120 days of moist curing, the increase in the compressive strengths for NSC and HPC were 23.3 and 8.8 percent respectively compared with 28 days strength.

Test results also showed that the compressive strength of concrete specimens exposed to oil decreased moderately with time. For the NSC specimens exposed to the oil, the maximum reduction values were about 15,19 and 25 percent for specimen exposed to crude oil, gas oil and kerosene for 120 days respectively. On the other hand, the maximum reduction value in the compressive strength of HPC specimens exposed to crude oil, gas oil and kerosene were about 6, 8 and 12 percent for 120 days respectively.

It is obvious from these results that the high performance concrete was less affected than NSC after exposure to oil. This can be attributed to the fact that the microstructure of high performance concrete with water-binder ratio of 0.3 especially those densifed with silica fume becomes so dense (**Holm and Bremner, 2000**) that it is difficult for the oil to penetrate into or through concrete .

Furthermore, test results showed that the reduction in the compressive strength of both types of concrete increases with decrease in viscosity of oil. For example, after 120 days of exposure to oil, the decrease in compressive strength was 25, 19 and 15 percent for NSC and 12, 8 and 6 percent for HPC exposed to kerosene, gas oil and crude oil respectively. This is attributed of the fact the mineral oil has no effect on the quality of concrete. The harm adjective of the oils depends on their viscosity, the higher viscosity of the oil, the less dangerous it is to concrete. Therefore viscosity of the oil is very important property for oil storage tanks (**Watson** and **Oyeka, (1981)**, **Spamer,(1944)** and **Hernibrock, (1944).**

4.2 Splitting Tensile Strength:

The test results of Splitting Tensile Strength of NSC and HPC exposed to different oils up to age of 120 days exposure are given in **Table (5). Figures (3) and (4)** showed the change in splitting tensile strength of the concrete specimens exposed to different oil compared with that of those cured in water of the same age. As shown in **Figures (3) and (4)**, the loss of splitting tensile strength resulting from exposure to oil was higher for NSC compared to the HPC. For the NSC, the loss in splitting tensile strength was of the order of 20, 17 and 10 percent of the water tensile strength for specimens exposed to kerosene gas oil and crude oil respectively. While for HPC the reduction was 10, 7 and 5 percent respectively with same exposure period of 120 days. It is clear from these results that the viscosity of oil had significant effect on splitting tensile strength of concrete during exposure to oil .

In addition, the test results for splitting tensile strength follow a somewhat similar pattern to that of compressive strength, but with a percent of reduction less than the reduction which was observed in compressive strength . This behavior is also noted by**AL-Hamdani (1991).**

<u>Conclusions:</u>

Based on the results of this study , the following conclusions can be drawn:

1- The loss on mechanical properties (compressive and splitting tensile strengths) resulting from exposure to oil was relatively smaller for HPC compared with NSC. The difference was about 10 percent.
2- The reduction in compressive and splitting tensile strengths of NSC and HPC increases with decrease in viscosity of oil in the entire period of exposure.
3- The test results for compressive strength follow a somewhat similar pattern to that of splitting tensile strength, but with a percent of reduction more than the reduction which were observed in tensile strength

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Table (1) Technical description of high range water reducing admixture (Typical Properties)

Main action	Concrete superplasticizer
Form	Viscous liquid
Color	Light brown
Relative density	1.1 @20^{o}C
PH value	6.6
Viscosity	128 $\pm$ 1.30cps @20^{o}C
Transport	No classified as dangerous
Labeling	No hazard label required

Table (2) Viscosity of oil used

Oil	Viscosity (Centipoises) at 25 ^{o}C
Kerosene	1.089
Gas oil	3.780
Crude oil	6.918

Table (3) Mix proportion and properties of concrete

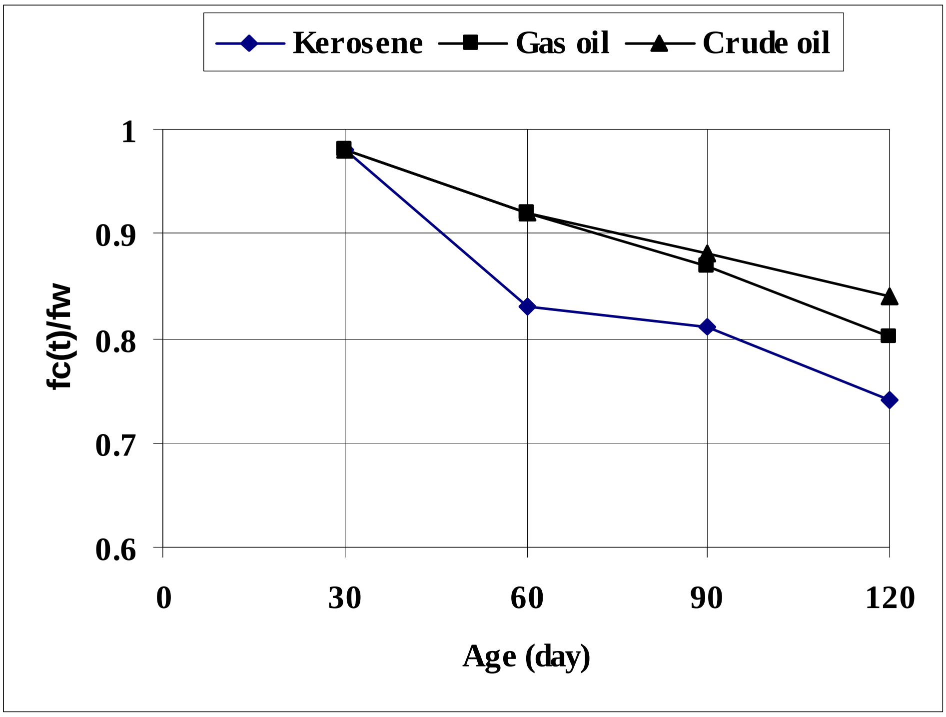
		NSC w/c= 0.5	HPC w/cm=0.3
Materials	Cement (kg/m^3)	300	543
	Water (kg/m^3)	150	177
	Coarse aggregate (kg/m^3)	1200	880
	Fine aggregate (kg/m^3)	650	750
	Silica fume (kg/m^3)	-	47
	HRWRA (kg/m^3)	-	14.75
Properties	**Fresh concrete**		
	Slump (mm)	80	85
	Hardened concrete		
	Compressive strength (MPa) 28-day	28	71
	Splitting tensile strength (MPa) 28-day	2.6	3.4

Table (4) Compressive strength results of the test specimens

Liquid	Age (day)	Compressive strength (MPa)	
		NSC	HPC
Water	28	23.10	71.00
	30*	25.30	75.50
	60*	26.70	76.60
	90*	27.20	77.00
	120*	28.50	77.31
Kerosene	30*	24.94	74.10
	60*	23.60	73.46
	90*	22.23	70.88
	120*	21.37	68.03
Gas oil	30*	25.01	74.80
	60*	24.63	73.23
	90*	23.92	72.81
	120*	23.08	71.11
Crude oil	30*	25.00	75.01
	60*	24.70	74.63
	90*	24.10	73.33
	120*	24.22	72.66
*After 28-day moist curing			

Table (5) Splitting tensile strength results of the test specimens

Liquid	Age (day)	Splitting tensile strength (MPa)	
		NSC	HPC
Water	28	2.40	3.41
	30*	2.68	3.85
	60*	2.75	3.88
	90*	2.81	3.98
	120*	2.96	4.01
Kerosene	30*	2.43	3.65
	60*	2.41	3.63
	90*	2.39	3.61
	120*	2.37	3.60
Gas oil	30*	2.48	3.75
	60*	2.47	3.74
	90*	2.46	3.73
	120*	2.45	3.72
Crude oil	30*	2.68	3.85
	60*	2.67	3.82
	90*	2.66	3.81
	120*	2.66	3.80
*After 28-day moist curing			



Figure(1) Relative change in compressive strength of NSC exposed to oil with time

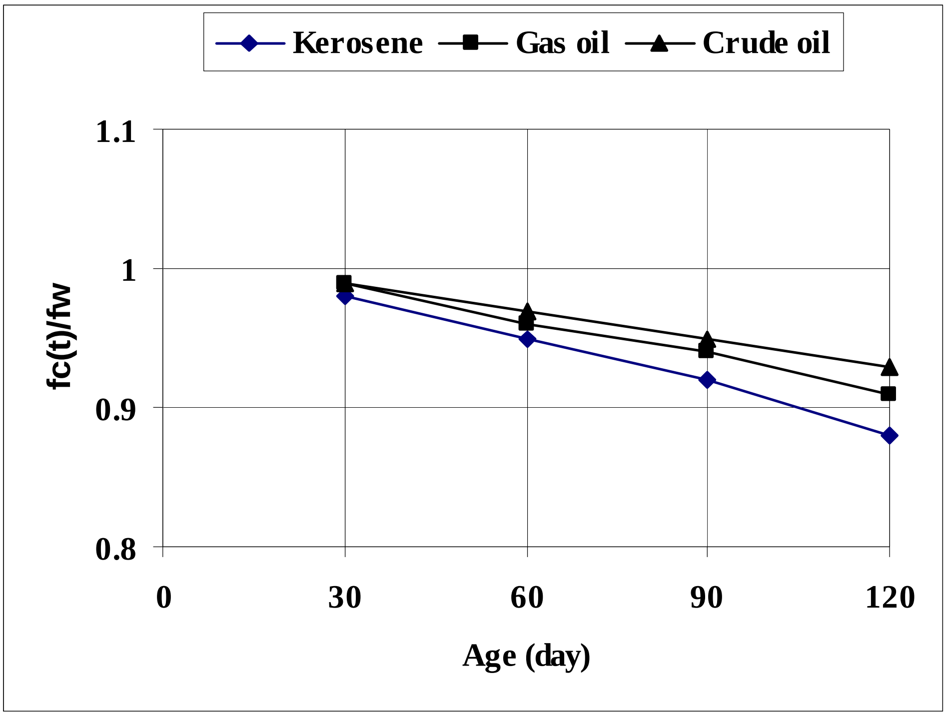


Figure (2) Relative change in compressive strength of HPC exposed to oil with time

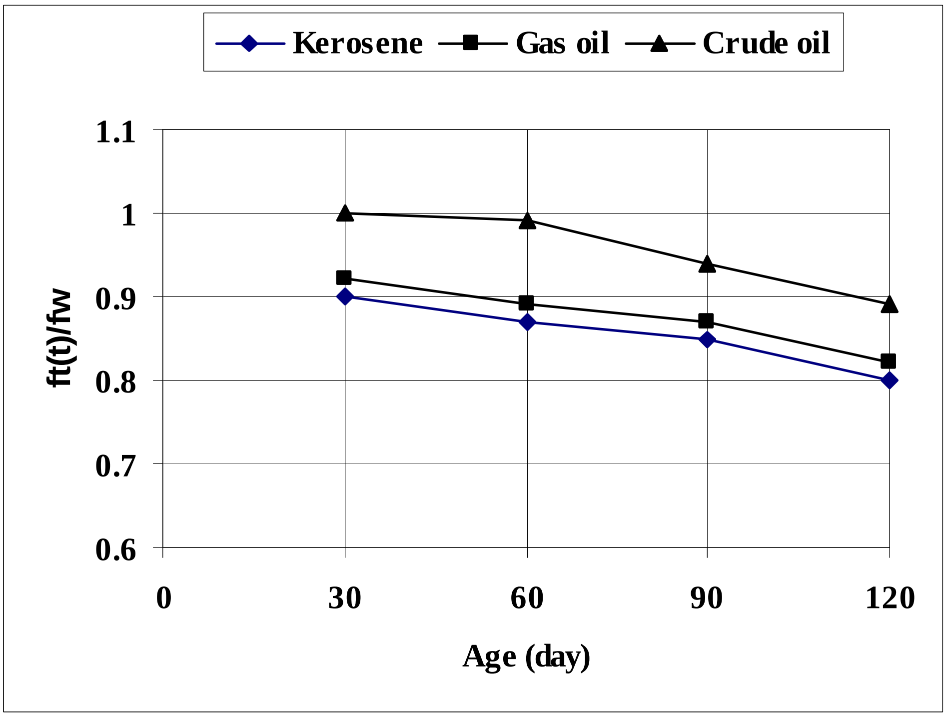


Figure (3) Relative change in splitting tensile strength of NSC exposed to oil with time

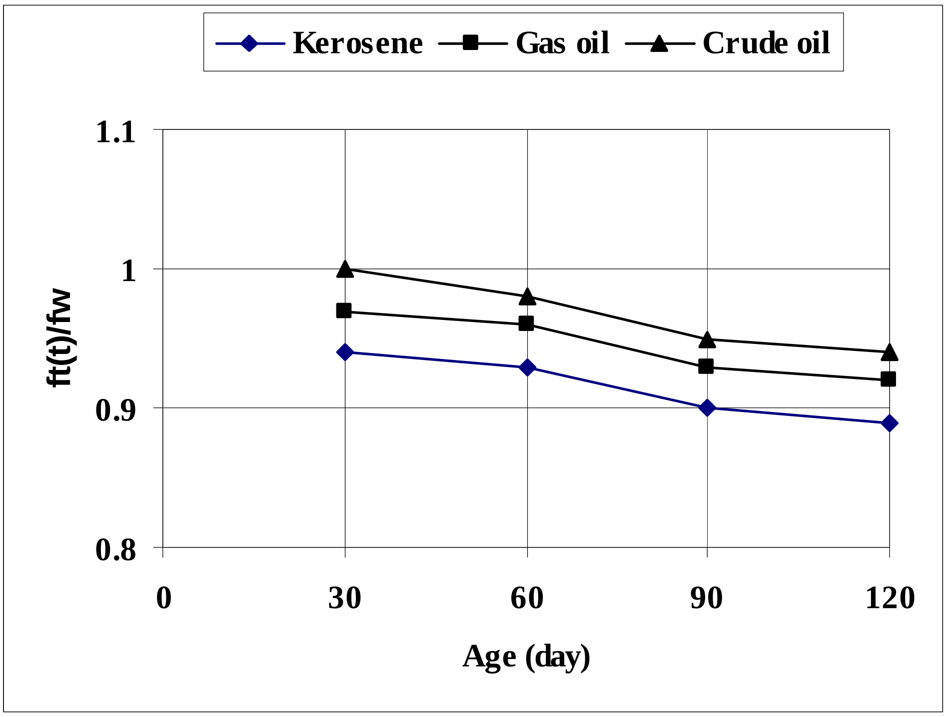


Figure (4) Relative change in splitting tensile strength of HPC exposed to oil with time