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Effect of using Sand Contaminated with Petroleum Products on Mechanical Properties of Concrete

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Abstract

The success of concrete and reinforced concrete in the construction of structures exposed to oil products depends on their strength and the age of service, in addition to the cost of construction and maintenance. Has already been diagnosed damage to many of the concrete structures exposed to crude oil and its products, such as oil reservoirs, foundations of machinery and floors of industrial buildings oil stores. Although many studies have been conducted on the behavior of hardened concrete exposed to petroleum products, the interpretation of their behavior is still vague and unclear and needs many other studies. The aim of the research is to explain the effect of the contamination of fine aggregate on some of the properties of the resulting concrete. An experimental program was implemented for this purpose. Fine aggregates were contaminated separately by benzene, gas oil and used-engine oil. The percentage of contaminations were 1.5, 3, 6 and 9% by weight of sand. The results of the tests showed a decrease in the compressive strength, tensile strength, bending strength and absorption which depends on the type and percentage of the oil product in the mix.

Keywords: Petroleum products, Sand contamination, Concrete, Compressive Strength, Tensile strength, Modulus of rupture, Absorption.

INTRODUCTION

The ability of oil products, especially light ones, is known to penetrate the concrete through cracks due to shrinkage, voids as well as joints, which are major problems that restrict the success of concrete as a construction material used in structures that store and transport oil products or those that are in contact with it such as floors in warehouses, refineries, factories, fuel stations, and others. Lea [1] explained that hydrocarbon products work on the packaging of unhydrated cement particles, which impede the process of hydration leading to decrease the strength of concrete and its development over time. Calabrese et.al [2] found that regardless of the type of sand and the high percentage of polluted petroleum, it leads to a decrease in the strength of concrete in the early and late ages. Ezeldin et.al [3] found that reinforced concrete beams made with fine aggregates contaminated with benzene could suffer a decrease in cracking and torque values of up to 30% and deflection would increase significantly when failure occurred. Hamad et al [4] study the effects of used engine oil on concrete properties and concrete behavior. The effect of used engine oil on properties of fresh and hardened concrete was investigated. Results indicated that used engine oil acted as an air-entraining agent by improving the slump and fluidity of the concrete mix, and enhancing the air content of fresh concrete. Reductions in the strength properties of hardened concrete due to the incorporation of oil were not as significant as when a commercial chemical air-entraining admixture was used. They found that UEO did not have significant effect on the structural behavior of reinforced concrete elements, where the ultimate load or load deflection diagrams have not been altered due to adding UEO to concrete mix ingredients. Ayininuola [5] studied the effect of gas oil and bitumen on the compressive strength of concrete, where sand was contaminated with both gas oil and bitumen at different ratios of weight of sand. Jassim and Jawad [6] found that oil-exposed concrete showed a decrease in compressive strength over time and the maximum reduction in the strength values of normal and high concrete specimens exposed to crude oil, gas oil and white oil for 120 days are about 25.19% and 12.86% respectively. Ajagbe et.al [7] investigated the compressive strength of concrete using fine aggregates contaminated with crude oil at different percentages of the weight of the sand used in the mixture. The results showed a slow rate of increase in the strength of concrete and increase in the rate of decrease as the percentage of pollutant increase. Abousnina et al [8] found that concrete made by fine sand contaminated with light crude oil, the cohesion increased significantly up to 1% of oil contamination and then decreased with increasing percentage of crude oil while a slight reduction in frictional angle was observed with oil contamination. The highest compressive strength was obtained for mortar with 1% oil contamination and with only a 18% decrease in strength of mortar with 10% oil contamination compared to the uncontaminated samples. Osuji and Nwankwo [9] observed that the presence of crude oil in concrete hinders the bond formation between constituent materials and brings about segregation. Consequently, the presence of crude oil in concrete resulted to variations in workability of the concrete the higher the percentages of crude oil in the fine aggregate, the higher the workability. Also, lower compressive strengths were observed in contaminated concrete cubes when compared with the control cubes. This revealed clearly that crude oil is a compressive strength inhibitor in the production of concrete. The higher the percentages of crude oil in the fine aggregate, the lower the compressive strength obtained. It can be inferred that the optimum crude oil contamination for the achievement of normal compressive strength is as low as 0.3%. Shafiq et al [10]found that the addition of used engine oil, concrete slump was increased by 18% to 38% and air content by 26% to 58% as compare to the slump of control concrete. Porosity and oxygen permeability of concrete containing used engine oil was also reduced and the compressive strength obtained was approximately same as that of the control mix. Shahrabadi1 and Vafaei [11] studied the effect of sands contaminated with kerosene on the compressive strength of conventional normal weight concrete. They found that a reduction up to 27% in the concrete compressive strength was occurred in 2% kerosene contaminated samples in the all exposure conditions studied.

Although many studies have been conducted on the behavior of hardened concrete exposed to petroleum products, the interpretation of their behavior is still unclear and needs to be studied. This research can be considered as an attempt to provide additional information on the effect of some oil products on the hydration process of concrete in its early age, in addition to study the effect of using soil contaminated with crude oil or its products in the manufacture of concrete.

EXPERIMENTAL PROGRAM

The experimental program was directed to determine the effect of the exposure of petroleum products on some of the properties of hardened concrete such as compressive strength, split cylinder tensile strength and modulus of rupture. The concrete mixture was (1: 1.5: 2) for cement, fine aggregates and coarse aggregate, respectively, and water to cement ratio (0.42). The variable was the type of polluted petroleum product namely gasoline, gas oil (diesel) and the used-engine oil. The percentage of the weight of the oil product to the weight of the sand used were (1.5, 3, 6% and 9%).

Mixing Materials

Cement is the Portland cement which is classified as the first type under the Libyan specifications (L. 340: 1997).

Fine aggregate is locally available sand from the Zliten area and the sieve analysis was carried out and the results showed that it was within the permissible limits according to BS882: 1992.

Coarse aggregate is a local irregular shape and the sieve analysis was carried out and the results showed that it was within the permissible limits according to the British specifications BS882: 1992. Tables 1 shows the sieve analysis of fine and coarse aggregates.

Table 1: Sieve analysis of fine and coarse aggregates

Fine aggregate			Coarse aggregate		
Sieve size (mm)	**Cumulative passing (%)**	**BS882:1992**	**Sieve size (mm)**	**Cumulative passing (%)**	**BS882:1992**
2.36	85.50	80-100	20	100	90-100
1.18	73.05	70-100	14	65	30-80
600 µm	63.00	55-100	10	32.83	30-60
300 µm	25.00	5-70	5	6.05	0-10
150 µm	0.40	0-15	-	-	-

Water: Drinking water free of salts, impurities and organic matter was used for mixing and treatment.

Petroleum products: Three types of petroleum products were used, namely gasoline, gas oil, and used motor oil, with specifications as follows:

Benzene:
Specific weight at 15.6° C = 0.7538
Density at 15° C = 753.5 kg / m^3
Sulfur Ratio = 0.01

Gas oil
Specific weight at 15.6° C = 0.8424
Density at 15° C = 842 kg / m^3
Sulfur Ratio = 0.051

Viscosity at 15° C = 3.44 mm^2 / sec

used-engine oil
Concentration of phosphorus = 1039 p.p.m
Concentration of zinc = 1034 p.p.m
Calcium concentration = 2870 p.p.m
Viscosity at 100° C = 9.42 Centistoke
Specific weight = 0.8923
Density at 15.6° C = 891.8 kg / m^3

Laboratory tests

Absorption test: This test is to dry the cubes in the oven at a temperature (105° C) for 24 hours and then be weighed and this is dry weight. The specimens were then immersed in water for (24) hours and was taken and weighed. The absorption ratio was calculated by the following formula:

$$\text{Absorption ratio} = \frac{(\text{wet weight} - \text{dry weight})}{\text{dry weight}} \times 100$$

Compressive strength Test: This test is performed in accordance with BS 1881, Part 116. *Tensile strength Test:* This test was performed in accordance with ASTM C496, 2003. *Bending strength (modulus of rupture):* This test was performed in accordance with ASTM C293, 2003.

All materials in the concrete mixture were weighed separately depending on the mixing ratios identified. Mixing oils with fine aggregates was done until all the fine aggregates were covered with the oil, then all the mixing materials were placed in the mechanical mixer and mixed well. All specimens were kept in molds for 24 hours, cured by immersion in water at laboratory temperature until test time at 28 days age.

RESULTS AND DISCUSSION

Figures (1), (2), (3) and (4) show the effects of the amount and the type of contaminating petroleum products on the concrete compressive strength, tensile strength (cylinder splitting strength), modulus of rupture and absorption. These figures show that for 1.5, 3, 6 and 9% of the contaminating oil and in comparison with the reference concrete the effects can be summarized as follows:

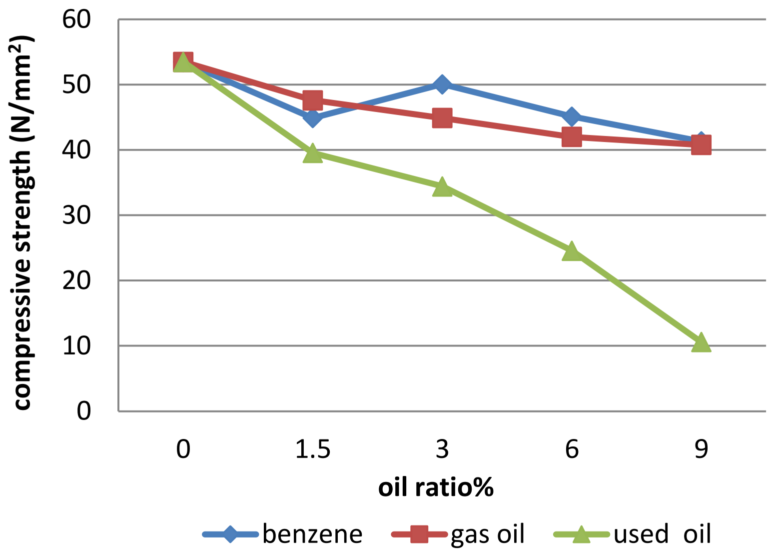

Figure 1: Effect of oils on compressive strength of concrete

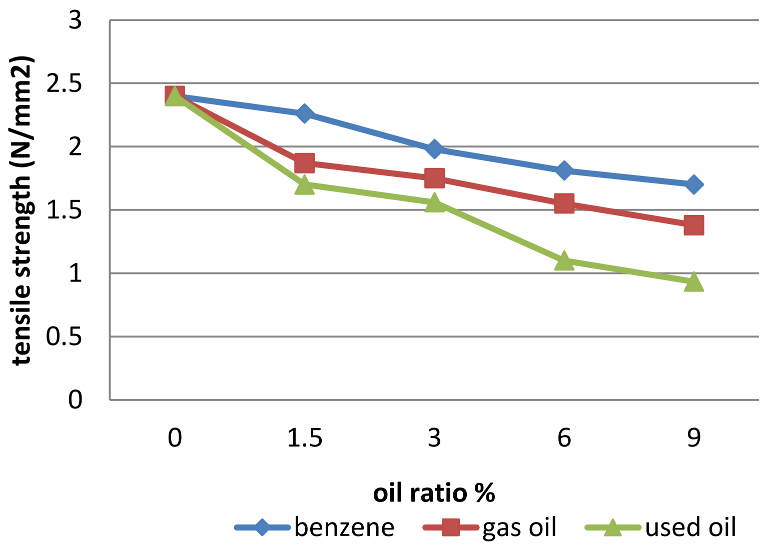

Figure 2: Effect of oils on tensile strength of concrete

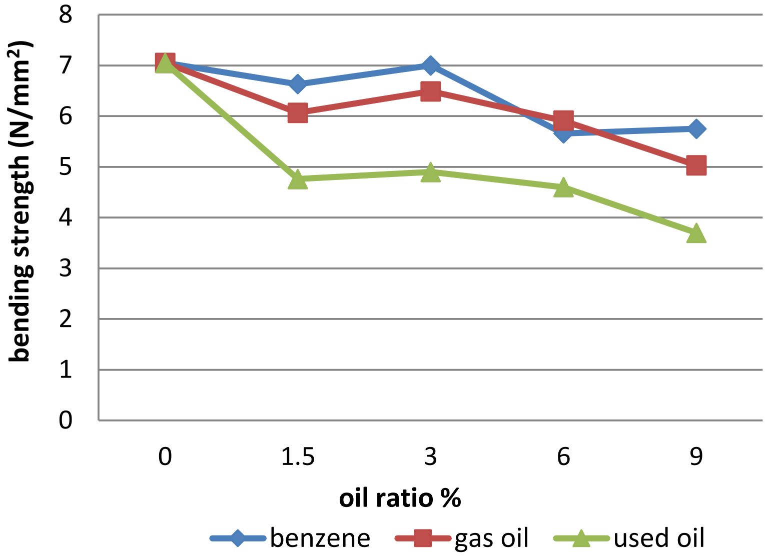

Figure 3: Effect of oils on bending strength (modulus of rupture)

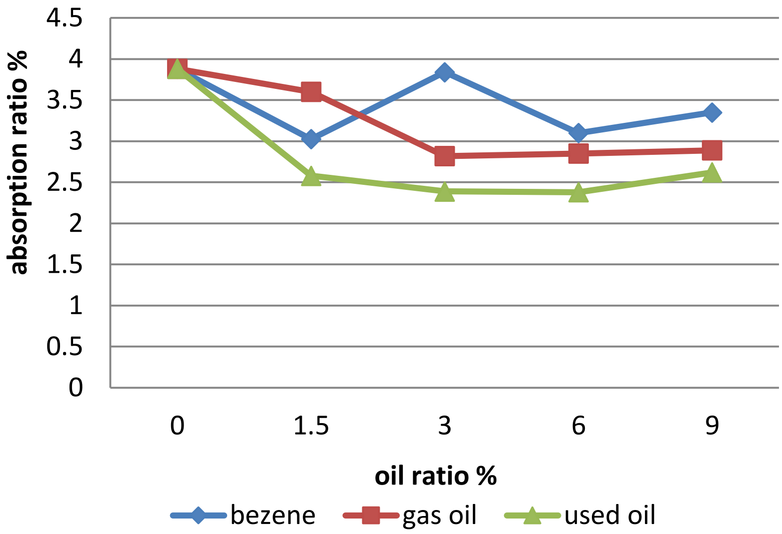

Figure 4: Effect of oils on concrete absorption

1. A decrease in compressive strength by 16.1, 6.4, 15.7 and 22.8%, respectively when using gasoline as a pollutant and when adding gas oil, the decrease was 11.0, 16.1, 21.5 and 23.8%, while the decrease was by 26.1, 35.6, 54.0 and 80.2% when using the used-engine oil for the same ratios respectively.
2. The decrease in tensile strength was about 5.8, 17.5, 24.6 and 29.2% when gasoline was added. While the addition of gas oil and the used-engine oil caused a decrease of (22.1, 27.1, 35.4 and 42.5%), (29.2, 35.0, 54.2 and 61.1%) respectively.
3. The modulus of rupture decreased when benzene was added by 6.0, 0.8, 19.7 and 18.4% respectively. While adding gas oil and the used motor oil at the same ratios caused a reduction by (13.9, 7.9, 16.2 and 28.7%) and (18.3, 30.5, 34.7 and 47.5%) respectively.
4. A decrease in the absorption ratio compared with the reference mixture which was 3.88% was noticed. But the absorption rate did not take the behavior of continuous decline with the increase in the proportion of the amount of oil product and showed this behavior clearly when adding gasoline

It is clear that the addition of petroleum products to the concrete in its fresh condition led to a decrease in compressive strength, tensile strength, modulus of rupture and absorption coefficient in the hardened stage which depended on the type of the polluting oil and its percentage. The effects increased with the increase of the percentage of the polluting oil with maximum values in the case of the used-engine oil followed by gas oil and then benzene which may be due to the following:

1. Penetration of oils to cement hydration products may cause an expansion in the voids of the gel and separation of these products from each other which leads to weak bonds between them, reduction in the cohesion forces on the surface of the gel and increase the possibility of sliding some of them in addition to the increasing of the internal hydraulic pressure as a result of absorption of these liquids.

2. Change in the concentration of oils in concrete leads to a decrease in the ratio of water content to moisture, which reduces the absorption of concrete for water during the curing period.

3. The pollution of sand with oils, which forms part of the internal structure of the concrete leads to the packaging of the surface area of the sand granules, weakens the forces of cohesion between them and cement paste. The oil layer around aggregates is responsible for the slow rate of development of concrete strength.

4. The thickness of the layer of oil coated to fine granules depends on the density of the product and its viscosity and therefore it is expected that the layer of oil used motor is the thickest while the thickness of the gasoline layer is the least and this thickness can be reduced due to evaporation due to heat from hydration process, which may contribute in explaining the difference in the effect on strength and absorption between oil types.

CONCLUSIONS

The main conclusions reached will be set out in the following points:

1. Compressive strength, tensile strength and bending strength (modulus of rupture) of concrete containing oil products decreases compared to the reference concrete without oils pollution. The higher the percentage of the oil product, the higher the decrease.

2. Concrete is affected by used motor oil more than gasoline and gas oil.

3. The pollution of sand with oils, which forms part of the internal structure of the concrete leads to the packaging of the surface area of the sand granules, weakens the forces of cohesion between them and cement paste. The oil layer around aggregates is responsible for the slow rate of development of concrete strength.

4. The absorption ratio of the concrete polluted with oil products is lower than that of the reference concrete.

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