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Investigation on Concrete Compressive Strength Mixed with Sand Contaminated by Crude Oil Products

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Abstract

This paper experimentally investigates the effect of contaminated sand with kerosene and diesel on the compressive strength of concrete. A total of 63 (9 control and 54 contaminated samples) standard concrete cubes having dimensions of 150mm×150mm×150mm were casted with sand contaminated with kerosene and diesel at different percentages of 0.5%, 1.0%, and 1.5%, respectively. The three percentages are calculated from the dry weight of the sand. The casted samples were tested in accordance to the ASTM standards at different curing time of 7days, 14day, and 28days, respectively. The test results showed a noticeable reduction in the concrete compressive strength as the contamination level increases. Compressive strength after 28 days at a contamination of 1.5% for kerosene and diesel specimens was found to be 32% and 42% lower than that of the ordinary concrete samples, respectively. It is concluded that special attention in the design and analysis of concrete should be considered under such conditions.

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Keywords; concrete, mix design, oil products, kerosene, diesel, compression tests

Introduction

Due to the global increase on oil products demand, the incidents of oil leakage have been increased significantly over the last two decades. Such incidents occur either from transporting the crude oil products from one place to another or from underground storage tanks, oil piping vandalism, and drilling [1]. The leakage of oil will result in increasing the hydrocarbon in the soil [2]. This oil spill contamination would impact the properties of the sand used in concrete construction. Investigators [3-8] recommended using the contaminated sand as road base materials or topping layer for car parks. Other recommendations were proposed to remove or clean the contaminated sand from crude oil products by different means such as bioremediation, thermal desorption, soil vapor extraction, soil washing, electrokinetic soil remediation and electrochemical remediation.

Few studies were found in the literature that investigates the effect of crude oil products on the geotechnical properties of different types of soils, specifically sand. Ghaly [9] concluded in his research that the angle of internal friction of the sand decreases with the increase in the percentage level of the oil. The effect of crude oil on the geotechnical properties of Kuwaiti sand was studied by Al-Sanad et. al. [10]. They showed in their study that the compressibility of the sand has increased due to the addition of crude oil. Shin et. al. [11] concluded that contaminated soil with oil possess a lower angle of internal friction than clean sand. Evgin and Das [12] studied the stress strain behavior of loose and dense sand when saturated with oil and water and found that contaminated sand with oil will reduce the angle of internal friction and increased the

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volumetric strain.

Researchers started to investigate the compressive strength of concrete mixed with contaminated sand and aggregate. Hamad et al. [13] studied the effect of used engine oil on the properties of fresh and hardened concrete. Their experimental program consisted of twenty concrete mixes that were prepared in two groups with different water/cement ratio of 0.62 and 0.59, respectively. The study concluded that used engine oil increased the slump, amount of entrained air of the fresh concrete mix, but did not adversely affect the overall strength of hardened concrete. However, Hamad et al. [13] recommended that further evaluation of the effect of used engine oil on the structural behavior of reinforced concrete elements is needed as well as more studies on the curing time and procedures on the effect of used engine oil on concrete properties.

Similarly, Diab [14] investigated the performance of compressive strength of low- and high-strength concrete soaked in mineral oil. The behavior of concrete cubes soaked in engine oils for 6 months was compared with those of oil-free concrete cubes serving as a benchmark. The study consisted of five different concrete mixes examine the negative impact of mineral oil on low- and high-strength concrete. It was concluded that the presence of oil on the concrete surfaces prevented the concrete cubes from achieving greater levels of strength. In addition, the existence of mineral oil in the concrete mix increased the compressibility of concrete, but decreased its elastic modulus.

The effect of sandy soil contaminated with crude oil on concrete compressive strength was also studied by Ajagbe et. al. [15]. A concrete mix of 1:1.8:2.7 with a water/cement ratio of

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0.5 was used for all specimens. The crude oil was added by percentage (2.5%, 5%, 10%, 15%, 20% and 25%) of sand weight to contaminate the mix. A total of 147 samples (21 control and 126 contaminated samples) were prepared and tested. It was observed that the crude oil reduced the compressive strength of concrete by 18-90% for the samples that were contaminated by 2.5-25%, respectively.

The main objective of this research is to investigate the effect of two crude oil products, namely kerosene and diesel on the compressive strength of concrete. A total of 63 samples will be prepared and tested after 7, 14 and 28 days, respectively. The sand will be contaminated with kerosene and diesel at different percentages of 0.5%, 1.0%, and 1.5%, respectively.

Experimental Program

Specimen Preparation

A total of 63 standard 150×150×150 concrete cubes were prepared. The concrete mixing procedure followed the British Standard BS 1881: Part 125: 1986 [16] and the concrete mix proportion design were conducted in accordance with the ACI 211.1-09 [17] guidelines. Different materials were used to produce the concrete mix tested in this study. The material were ordinary Portland cement (OPC), coarse aggregate (CA), fine aggregate (FA), water, crushed and dune sand. Table 1 shows the concrete mix proportions used in this study.

The same concrete mix presented in Table 1 was used for all prepared samples and mixed with different percentage of the two oil products (kerosene and diesel) of 0.5, 1.0 and 0.5%, respectively. It should be noted that the oil products were added to the sand prior to the mix. Tables 2 and 3 show the specifications of the used kerosene and diesel products, respectively.

The materials were mixed in a rotary mixer to produce a homogenous freshly mixed concrete. After which the mix was poured in standard steel cubic molds (150×150×150mm). Mechanical vibration for the poured concrete took place using a shake table to remove trapped air. Afterwards, the top surfaces of the concrete specimens were smoothly troweled and leveled. The concrete cubes were removed from the molds after 24 hours and immersed in water for curing. The compressive strength tests of the specimens were conducted after 7, 14 and 28 days. Figure 1 shows a sample of the casted mixes.

Experimental Procedure

The following procedure was adopted to prepare, test, and investigate the effect of the contaminated sand with the two crude oil products on the compressive strength of concrete:

- A total of four mix batches were prepared. Three of the mix batches were mixed with contaminated sand with kerosene and diesel at three different percentages of 0.5, 1 and 1.5%, respectively. The fourth concrete mix batch was prepared with clean sand to serve as a control specimen.
- Three identical samples from each batch were tested in compression using a universal testing machine (UTM) at 7, 14 and 28 days from the beginning of curing time.
- The concrete compressive strength testing procedure followed the ASTM C39 [19] with a loading rate of 7 kN/min.

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- Stress-strain curves, compressive strength and the associated failure modes of the tested specimens were collected for analysis.

Experimental Results

The results of the experimental program are summarized in Table 4 and Figs. 2-7. Table 4 lists the average concrete compressive strength of three identical samples for each batch at 7, 14, and 28 days, respectively. The specimens are designated in Table 4 as C, K and D to present the control, kerosene and diesel specimens, respectively. The number that follows the letter for K and D represents the percentages of kerosene and diesel in the sand. As mentioned earlier, the average compressive strength value was based on three identical specimens tested on the same day. Table 4 shows that the concrete compressive strength increases with the increase in curing time for all specimens. Figures 2(a) and 2(b) show a graphical representation of the obtained data listed in Table 4 for the specimen tested with contaminated kerosene and diesel, respectively.

It is obvious from Table 4 and Fig. 2 that contaminated sand with kerosene and diesel would adversely affect the compressive strength of concrete. Furthermore a noticeable reduction in compressive occurs at 0.5% contamination for both oil crude products. The concrete compressive strength for the specimens mixed with 1.0 and 1.5% of the crude oil products are comparable to that specimen with 0.5% contamination. Figure 3 shows the percent reduction of compressive strength for the contaminated specimens relative to the control specimen (C) at 7, 14, and 28 days, respectively. It should be noted that the percent reduction was computed using Eq. 1.

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$$\frac{\text{Control Specimen - Contaminated Specimen}}{\text{Control Specimen}} \times 100\% \qquad (1)$$

As shown in Fig. 3, the highest obtained reduction in the concrete compressive strength was 32% and 42% for the specimens contaminated with kerosene and diesel at 1.5%, respectively. Figure 4 compares the compressive strength results of the samples contaminated with kerosene and diesel at 7, 14 and 28 days, respectively. It is indicated from Fig. 4 that the specimens contaminated with kerosene achieved higher compressive strength than those contaminated with the same percentages of diesel. Further, a slight increase in the compressive strength of concrete is apparent when the kerosene percentage is 1%. The largest difference between kerosene and diesel occurred at 1% contamination with the later achieved a lower compressive strength of about 25% at 28 days. It seems that diesel negatively affect the bond interlock between the different concrete components. This was also noticed during casting were the concrete workability was reduced significantly. In addition, this was also shown in the failure modes of the tested cubes shown in Fig. 5. It should be noted that the tested specimens failed in a regular crushing manner.

Figure 6 shows the axial stress-strain response curves for selected specimens contaminated with the oil products (kerosene and diesel) at different percentages and curing times, respectively. Figure 7 shows the axial strain at the attained ultimate load versus the contamination percentage level at different curing times for all the tested specimens. It is clear from Fig. 7 that the behavior varies according to the contamination percentage and age of the

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specimens. In general, the control specimens achieve higher ductility compared to the contaminated specimens.

Summary and Conclusion

A total of 63 standard concrete cubes having dimensions of 150mm×150mm×150mm were casted and tested to study the effect of kerosene and diesel on concrete compressive strength. The sand was mixed with three levels of kerosene and diesel of 0.5, 1 and 1.5% , respectively. Compression tests have been conducted on the concrete cubes at 7, 14 and 28 days of casting. The following observations and conclusions were drawn:

- Contaminated sand with kerosene and diesel would adversely affect the compressive strength of the concrete mix.
- Specimens contaminated with diesel showed lower compressive strength than those contaminated with the same percentages of kerosene.
- The highest reduction in the concrete compressive strength was 32% and 42% for the specimens contaminated with kerosene and diesel at 1.5%, respectively.
- Diesel negatively affects the bond interlock between the different concrete components.
- Overall, the control uncontaminated specimen achieved higher ductility than the contaminated specimens.

Acknowledgement

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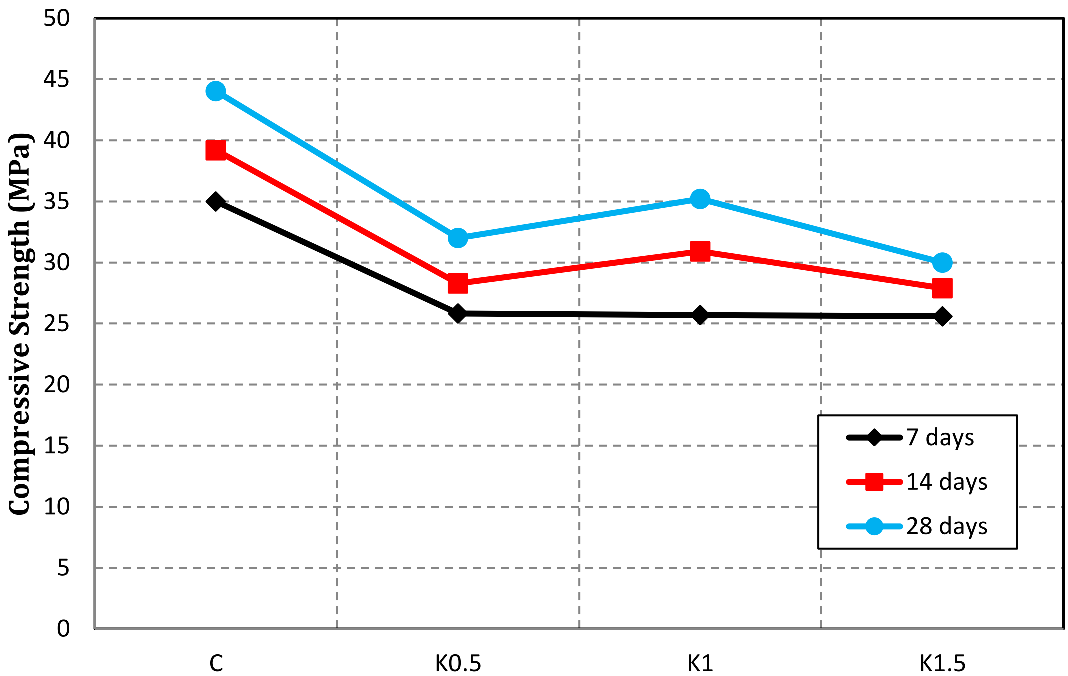
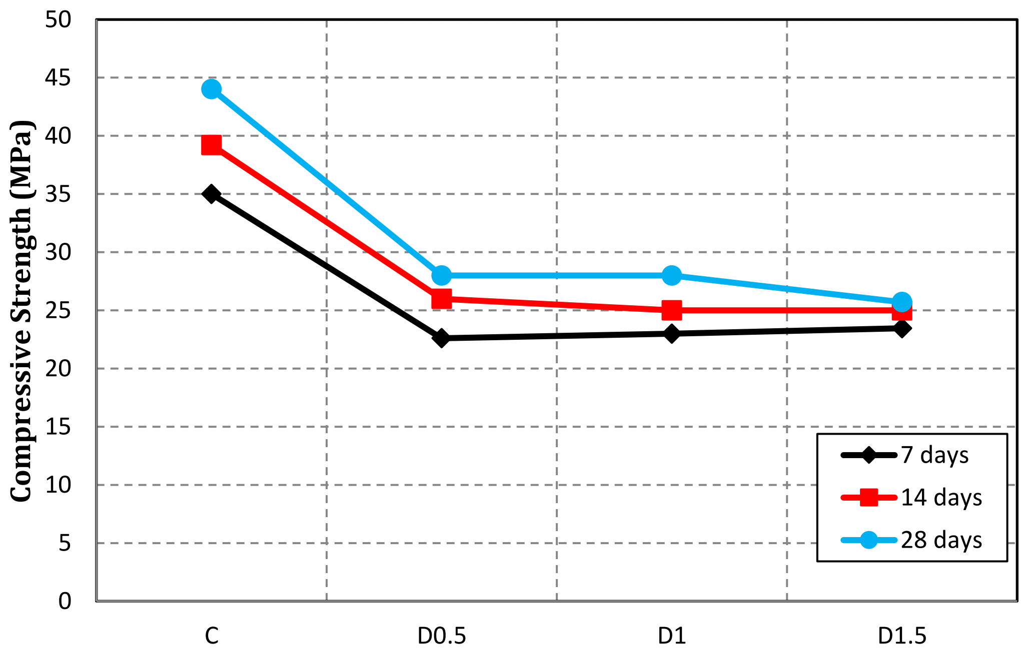
List of Figures:

Fig.1. Sample Preparation

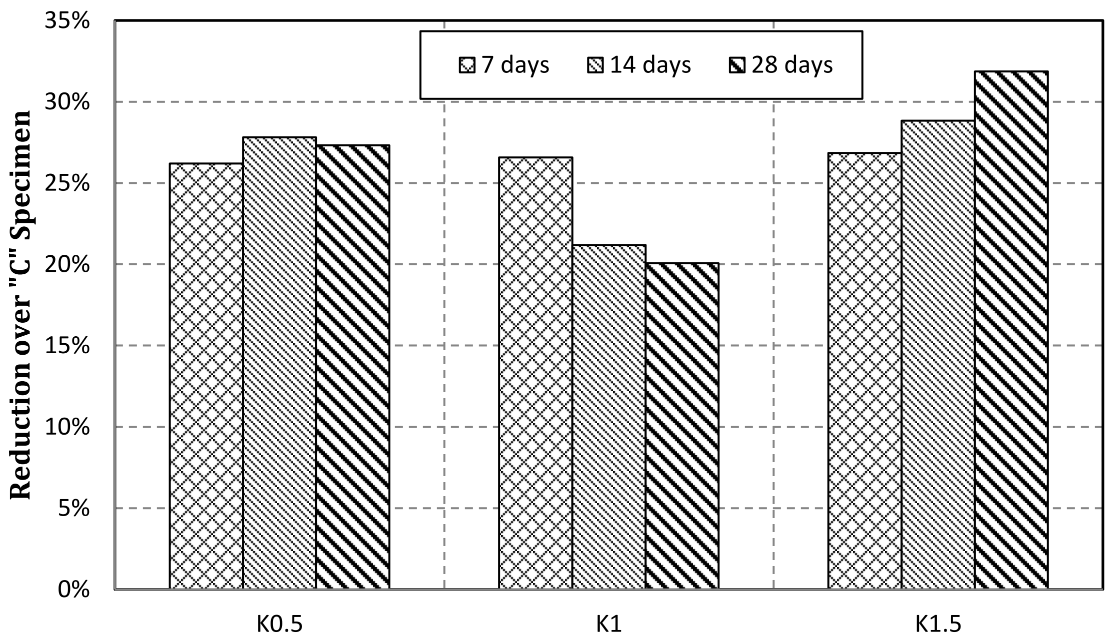


(a) Specimen casted with different kerosene percentages



(b) Specimen casted with different diesel percentages

Fig.2. Average compressive strength for the tested specimens at different curing time



(a) Kerosene

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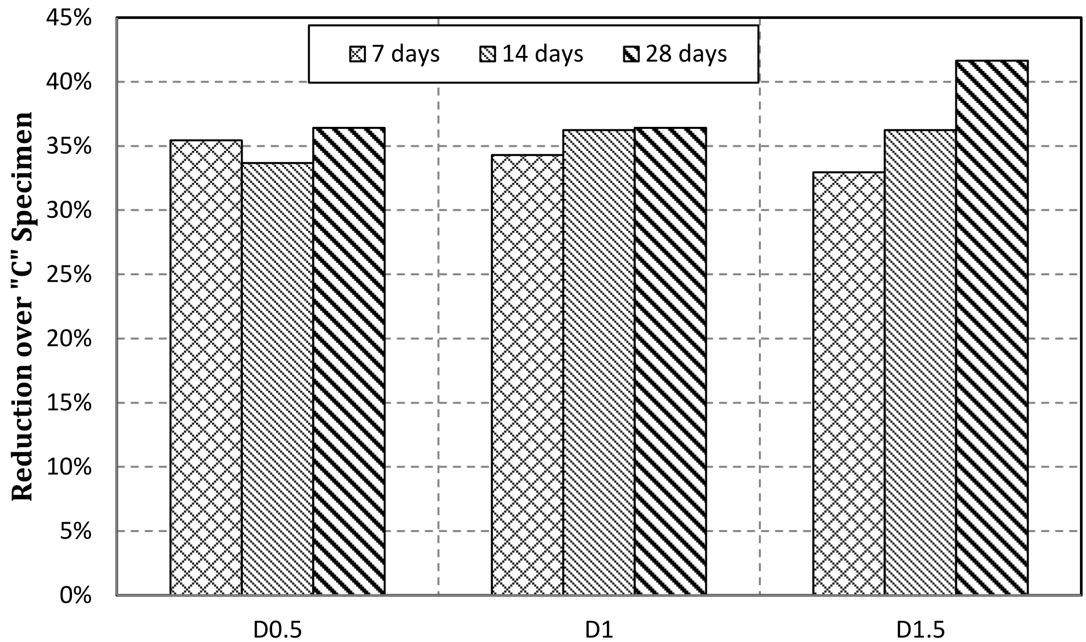
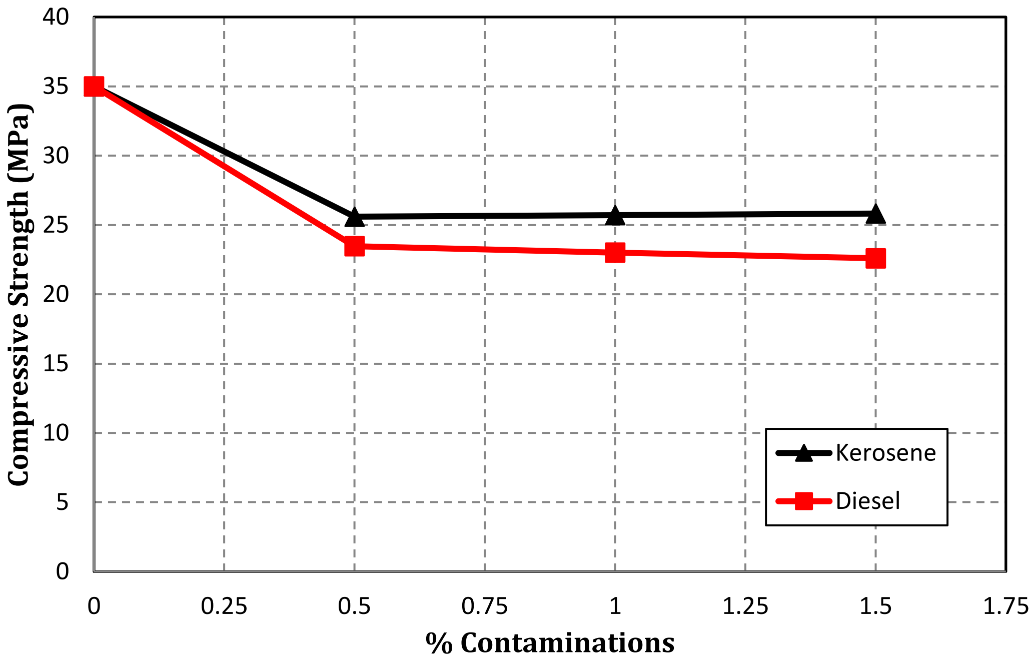
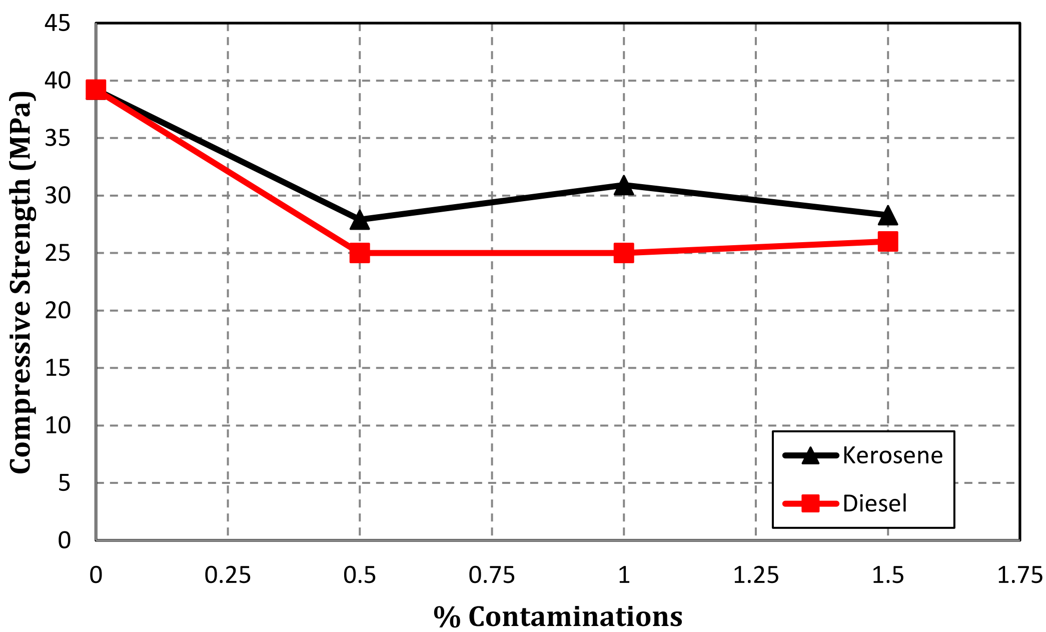


(b) Diesel

Fig.3. Percent reduction in compressive strength over the control specimen “C”



(a) At 7 days



(b) At 14 days

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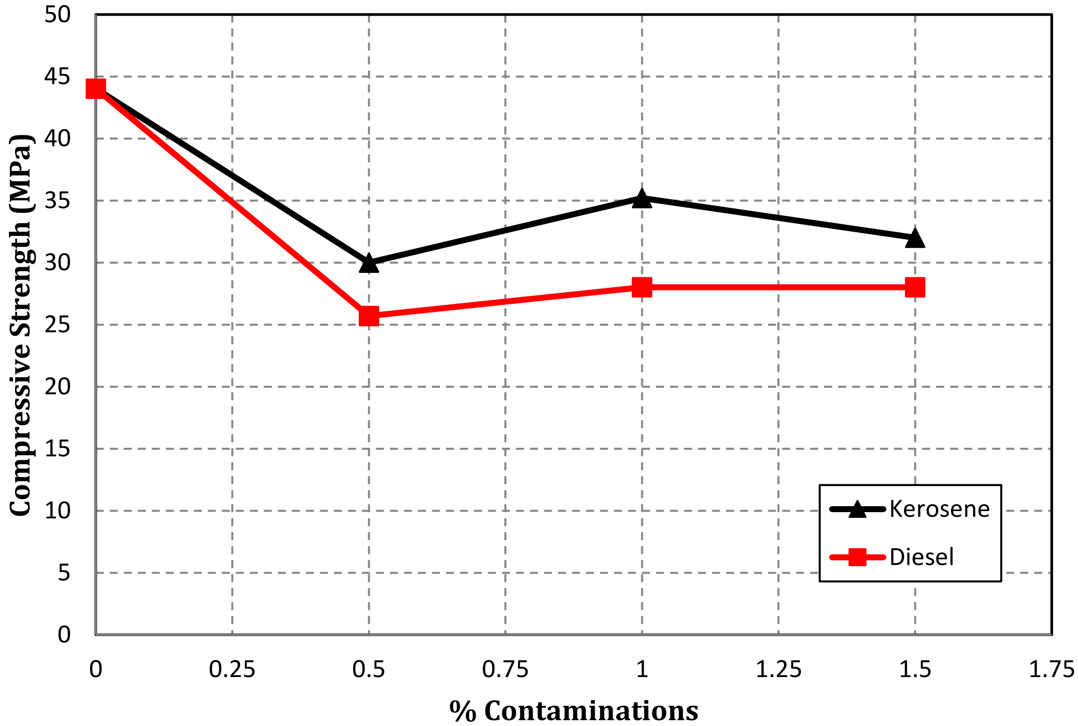

(c) At 28 days

Fig.4. Comparison between the different specimens tested at 7, 14 and 28 days

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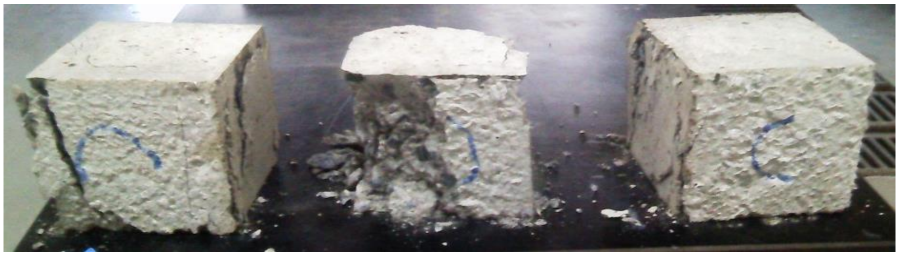

(a) Control specimens at 7 days

(b) Specimens contaminated with 0.5% diesel at 7 days

(c) Specimens contaminated with 1% diesel at 7 days

(d) Specimens contaminated with 1.0% kerosene at 14 days

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(a) Specimens contaminated with 1.5% kerosene at 28 days

Fig.5. Failure mode of the tested specimens

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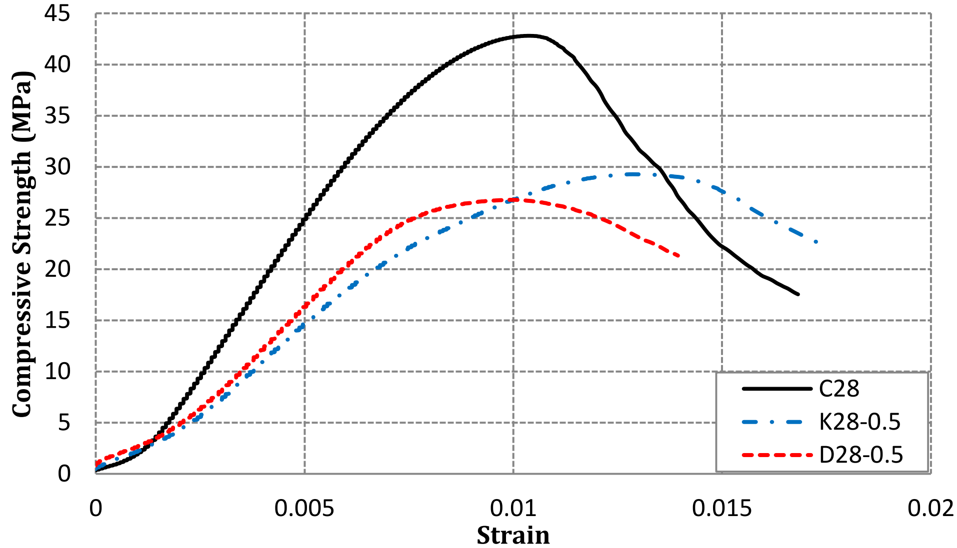
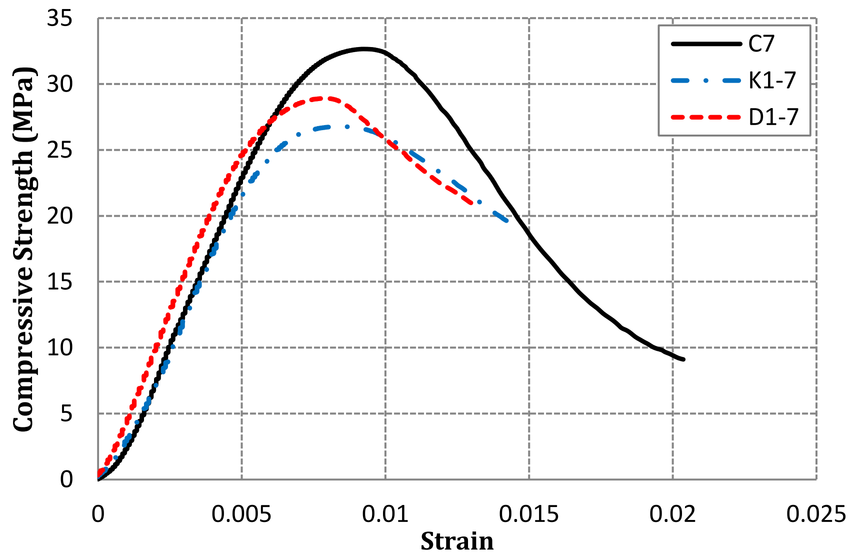


(a) 0.5% contamination at 28 days compared with the control specimen



(b) 1.0% contamination at 7 days compared with the control specimen

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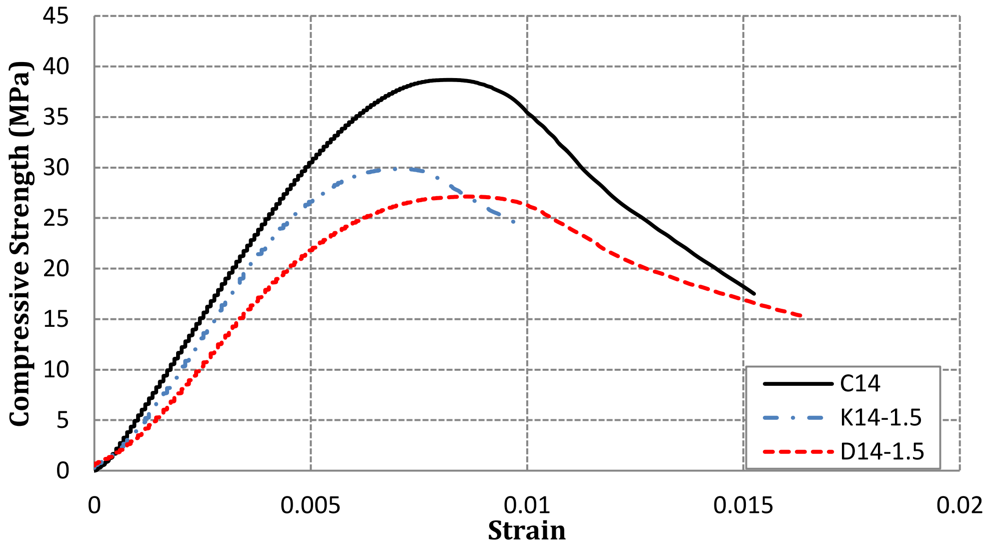

(c) 1.5% contamination at 14 days compared with the control specimen

Fig.6. Stress-strain response curves for selected specimens contaminated with the oil products

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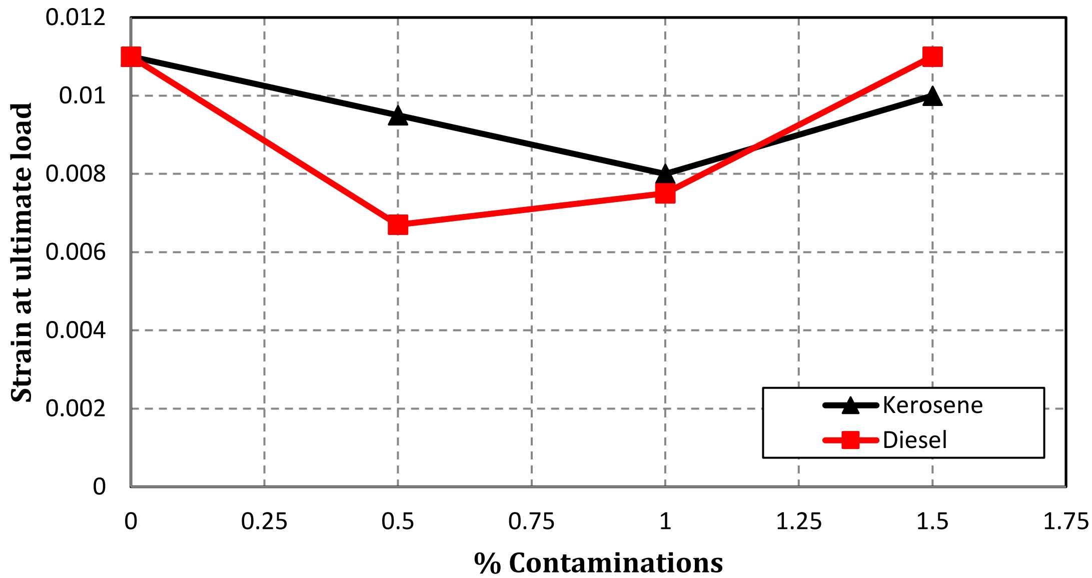

(a) 7 days

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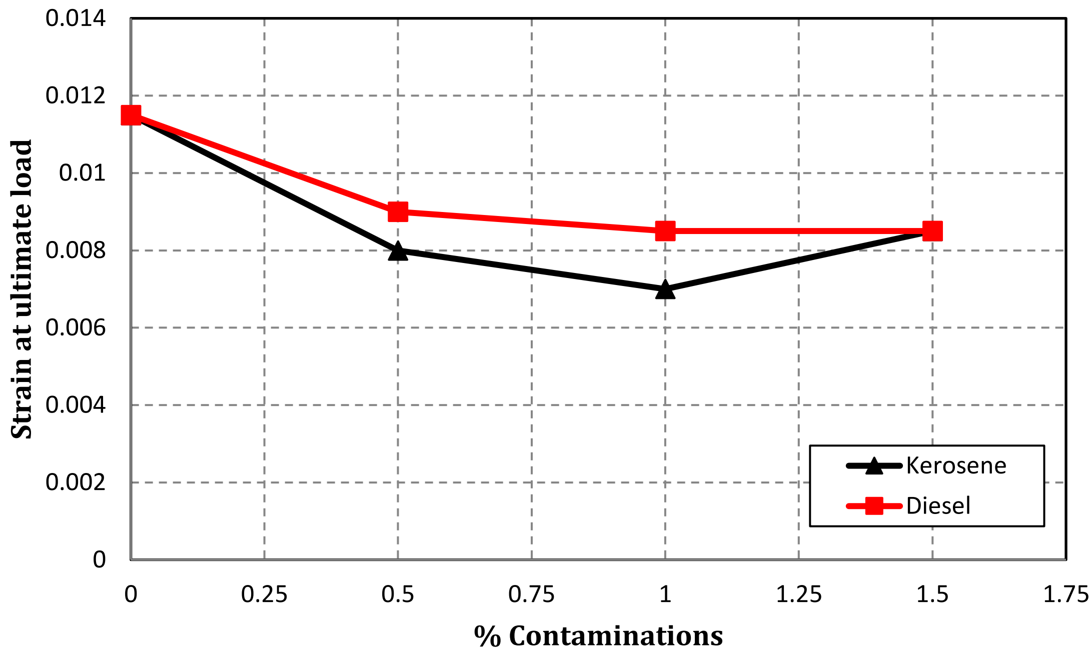
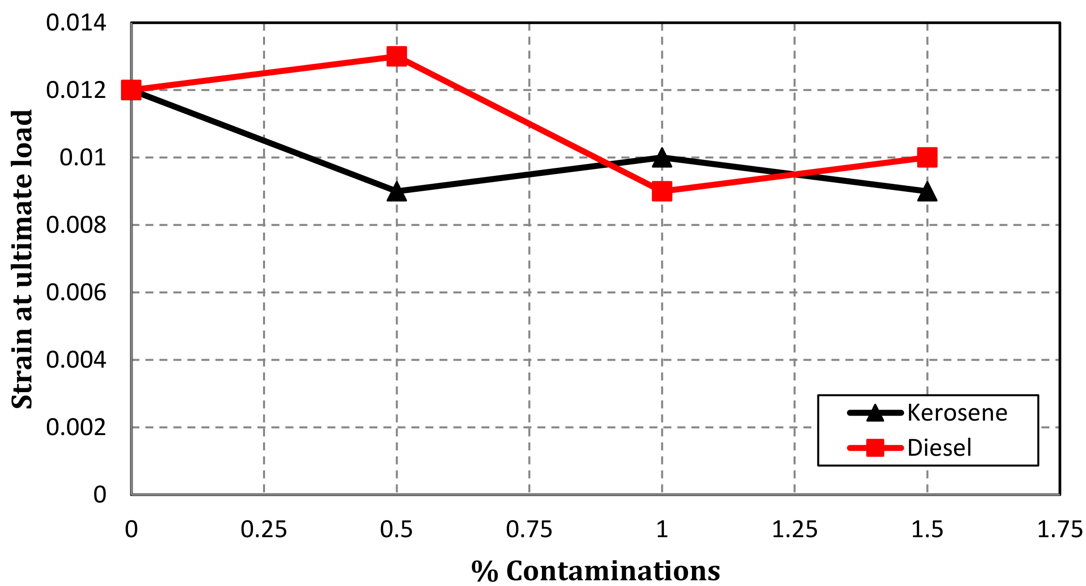


(b) 14 days



(c) 28 days

Fig.7. Comparison of the axial strain at the achieved ultimate load

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Table 1 Typical concrete mix proportion As per ACI 211.1-09

Material	Weight	
	1 m^3	Trial (0.02 m^3)

Cement (kg)	400	8.0
Water (L)	190	3.8
Aggregate 20 mm (kg)	500	10.0
Aggregate 10 mm (kg)	500	10.0
Crushed Sand (kg)	444	8.88
Dune Sand (kg)	296	5.92

Table 2 Specifications of the kerosene (ADNOC, [18]) used in this study

Tests	Limit
Density at 15˚C (kg/l)	0.775-0.830
Flash Point (˚C)	Min 38 ˚C
Corrosion, Copper Strip (3 hrs @ 50 ˚C)	Max 1
Total Sulphur (ppm/wt)	Max 3000
Strong Acid No. (mg KOH/g)	0.0 (Nil)

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Table 3 Specifications of the diesel (ADNOC, [16]) used in this study

Tests	Limit
Density at 15˚C (kg/l)	0.82-0.845
Flash Point (˚C)	Min 65
Corrosion, Copper Strip (3 hrs @ 50 ˚C)	Max 1
Total Sulphur (mg/kg)	Max 500
Strong Acid No. (mg KOH/g)	Max 0.1

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Table 4 Average concrete compressive strength of the different specimens

Specimen	C	K0.5	K1	K1.5	D0.5	D1	D1.5
7 days	35	25.8	25.7	25.6	22.6	23	23.47
14 days	39.2	28.3	30.9	27.9	26	25	25
28 days	44.0	32	35.2	30	28	28	25.7