Construction and Building Materials 47 (2013) 99–103

Contents lists available at SciVerse ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Investigation on concrete compressive strength mixed with sand contaminated by crude oil products

M. Attom, R. Hawileh *, M. Naser

Department of Civil Engineering, American University of Sharjah, P.O. Box 26666, Sharjah, United Arab Emirates

HIGHLIGHTS

- Sand is contaminated with crude oil products.
- Kerosene and diesel are the used oil products.
- Contaminated sand is used in the concrete mix.
- Compression tests were conducted.
- Compressive strength was reduced significantly when contaminated sand is used.

ARTICLE INFO

Article history:
Received 17 December 2012
Received in revised form 16 April 2013
Accepted 26 April 2013
Available online 30 May 2013

Keywords:
Concrete
Mix design
Oil products
Kerosene
Diesel
Compressive strength

ABSTRACT

The leak of oil products due to the huge demand would result in contaminating the sand that might be used in the concrete industry. This paper experimentally investigates the effect of contaminated sand with kerosene and diesel on the compressive strength of conventional normal weight concrete. The experimental program consisted of testing standard concrete cubes casted with sand contaminated with kerosene and diesel at different percentages of 0.5%, 1.0%, and 1.5%, respectively by the dry weight of the sand. In addition, uncontaminated samples were casted to serve as benchmark (control) specimens. The casted samples were tested in accordance with the ASTM standards at different curing times. The test results showed a noticeable reduction up to 42% in the concrete compressive strength as the contamination level increases. The results of this investigation imply that special attention in the design and analysis of concrete should be considered when contaminated sand is found in the mix.

1. 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 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.

* Corresponding author. Tel.: +971 6 515 2496; fax: +971 6 515 2979.
E-mail addresses: mattom@aus.edu (M. Attom), rhaweeleh@aus.edu (R. Hawileh).

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http://dx.doi.org/10.1016/j.conbuildmat.2013.04.042

Table 1
Typical concrete mix proportion as per ACI 211.1-09.

Material	Volume	
	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.

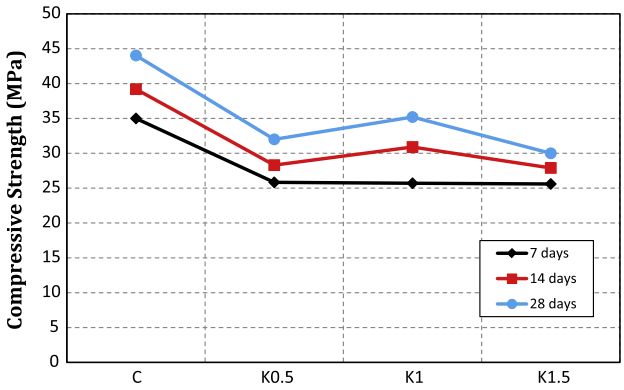
Tests	Limit
Density at 15 °C (kg/l)	0.775–0.830
Flash point (°C)	Min 38 °C
Corrosion, copper strip (3 h @ 50 °C)	Max 1
Total sulfur (ppm/wt)	Max 3000
Strong acid no. (mg KOH/g)	0.0 (Nil)

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

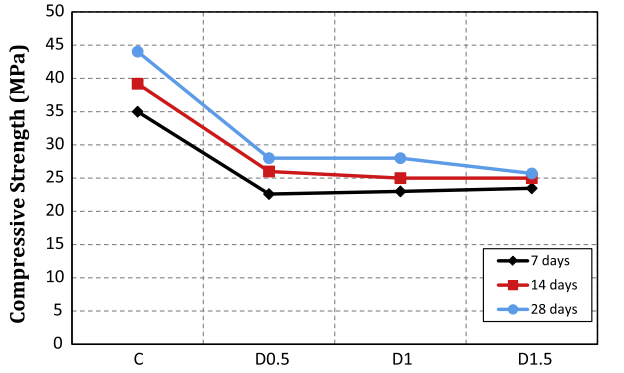
Tests	Limit
Density at 15 °C (kg/l)	0.82–0.845
Flash point (°C)	Min 65
Corrosion, copper strip (3 h @ 50 °C)	Max 1
Total sulfur (mg/kg)	Max 500
Strong acid no. (mg KOH/g)	Max 0.1

Fig. 1. Sample preparation.

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.



(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) specimen casted with different kerosene percentages, (b) specimen casted with different diesel percentages.

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 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.

Table 4
Average concrete compressive strength of the different specimens.

Specimen	C (MPa)	K0.5 (MPa)	K1.0 (MPa)	K1.5 (MPa)	D0.5 (MPa)	D1.0 (MPa)	D1.5 (MPa)
7 days	35.0	25.8	25.7	25.6	22.6	23.0	23.5
14 days	39.2	28.3	30.9	27.9	26.0	25.0	25.0
28 days	44.0	32.0	35.2	30.0	28.0	28.0	25.7