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Effect of kerosene impacted sand on compressive strength of concrete in different exposure conditions

Hamid Shahrabadi[1], Davoud Vafaei[2]
[1,2] *Lecturer, Faculty member of Chabahar Maritime University, Chabahar, Iran.*

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*Corresponding Author. h.shahrabadi@cmu.ac.ir , d.vafaei@cmu.ac.ir

Abstract
The leakage of oil products would result in contaminating the sands which are used in the concrete industry. In this study, the effect of sands contaminated with kerosene on the compressive strength of conventional normal weight concrete has been evaluated in various exposure conditions. Kerosene (0, 0.5, 1, 2, 4, 6 and 8%, by weight of sand) was used to contaminate sand to prepare concrete specimens. Produced specimens were subjected to three exposure conditions: clean potable water (CPW), tidal environment and sea water. To evaluate the effect of kerosene soaked environment on compressive strength of concrete, a number of 12 uncontaminated samples were immersed in kerosene. The maximum strength reduction in the samples immersed in sea water was occurred. A reduction up to 27% in the concrete compressive strength was occurred in 2% kerosene contaminated samples in the all exposure conditions studied. Subjecting concrete to kerosene soaked environment was not significant, however using contaminated sand adversely affect the compressive strength of concrete. Careful attention in design and analysis of concrete that has been produced from kerosene contaminated sand (KCS) should be considered.

Keywords: Kerosene, Compressive strength, Concrete, Exposure conditions

Introduction
The most commonly used material in the construction industry is Concrete. Concrete is a mixture of cement, water, fine aggregate and coarse aggregate, which hardens to a stone-like mass [1]. In addition to high strength, ease of production, low cost, good compatibility with other materials especially with steel, durability under aggressive conditions are some benefits of this material [2]. Most factors affecting the compressive strength of concrete are water/cement ratio, mix ratio, degree of compaction, type of cement, aggregate grade, design constituent, mixing method, placement, curing method and the presence of contaminates [3,4].
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) which is more commonly known as ultra-high performance reactive powder concrete (RPC) [5]. Reactive powder concrete (RPC) is coarse aggregate-free concrete, which has limited applications so far recorded in the construction industry [6].
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 [7].
Over the last two decades, the incidents of oil leakage have been increased significantly. Leaking of hydrocarbon from crude oil products storing and transporting systems, oil piping vandalism, drilling and oil exploration activities are some reasons for hydrocarbon contamination [8]. Such continually leakage results in increasing the amount of hydrocarbon contamination in soil and the environment. Using such impacted soil in concrete construction would influence the concrete properties.
A number of researchers have investigated the effect of hydrocarbon impacted sand on different properties of concrete. Attom et al. [9] studied the effect of contaminated sand with two crude oil products, i.e. kerosene

and diesel, on the compressive strength of conventional normal weight concrete. The crude oil products were added by different percentage including 0.5, 1, and 1.5% (by weight, dry basis) to contaminate the mix.
Ajagbe et al. [4] studied the effect of Crude Oil Impacted Sand (COIS) on the compressive strength of concrete. They produced 147, 100 mm concrete cubes (21 control and 126 contaminated samples) with concrete mix of 1:1.8:2.7 and w/c of 0.5. The compressive strengths of cubes were determined at ages 3, 7, 14, 28, 56, 84, and 168 days. In order to contaminate the sand, crude oil of 2.5, 5, 10, 15, 20 and 25% (by weight of sand) was used. Hamad et al. [10] investigated the effect of used engine oil on properties of fresh and hardened concrete. Diab [3] investigated the impact of used engine oil on the compressive strength of low- and high-strength concrete.
Exposure conditions in marine environment plays an important role on different properties of concrete. A number of researchers investigated on the effects of exposure conditions on different types of concretes. Valipour et al. [11] studied the performance of concretes containing natural zeolite, metakaolin and silica fume and that of concretes with different water-to-binder ratios under various exposure conditions (tidal, splash, atmosphere and soil). Dousti et al. [12], focused on the chloride binding characteristics of concrete samples exposed to an external source of chlorides from the sea water at Persian Gulf region. The effect of different exposure conditions on the chloride diffusion properties into concrete in the Persian Gulf region has been investigated by Ghods et al. [13].
This study is focused on the effect of kerosene on the compressive strength of ordinary Portland cement concrete. In order to investigate the influence of exposure conditions, after 24 hours was passed from concrete mix placement, the specimens were subjected to three exposure zones including CPW, tidal and sea water. Some specimens in tidal environment are shown in Figure 1. In order to evaluate the effect of kerosene soaked environment on compressive strength of concrete a number of 12 uncontaminated samples, 24-hours old, were immersed in kerosene. A total number of 264 samples were prepared and tested after 3, 7, 14 and 28 days. The sands were contaminated with kerosene at different percentage values including 0.5, 1, 2, 4, 6 and 8%.

Fig. 1: specimens in tidal environment

2. Experimental

2.1. Materials and Methods

2.1.1. Cement

Ordinary Portland Cement (OPC) was used in this study which is the most common cement used in general concrete construction. OPC contains some properties that can act as a binding agent in the presence of water.

2.1.2. Water

Clean potable water was used for concreting; the water aided the hydration of cement, which resulted in setting, and hardening of the concrete.

2.1.3. Aggregates

One half of the coarse aggregate (CA) used had a maximum size of 10 mm and the second half had a maximum of 20 mm. Fine aggregate (FA) was natural sand obtained from Chabahar, the south of Sistan and Baluchestan, Iran. Both the fine and coarse aggregates were air dried to reach the saturated-surface-dry condition to ensure the water/cement ratio is not affected. The particle size distribution of the fine and coarse aggregates are shown in Figures 2 and 3, respectively. From these figures, it was deduced that the fine and coarse aggregates are well graded. The sieve analysis of aggregates were performed in accordance with ASTM C 136 [13].

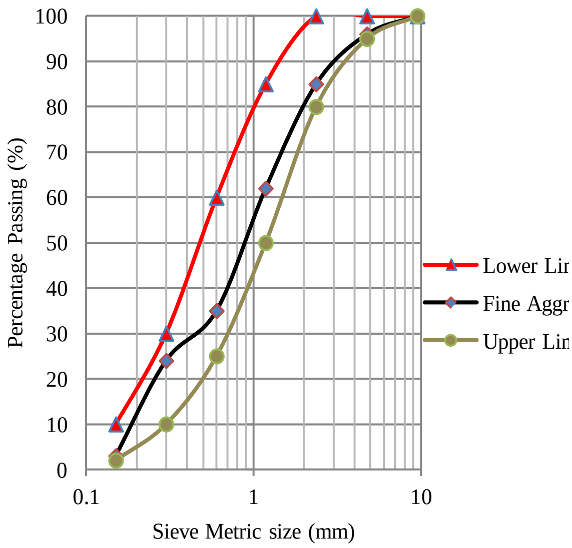


Figure 2: Particle size distribution curve of fine aggregate.

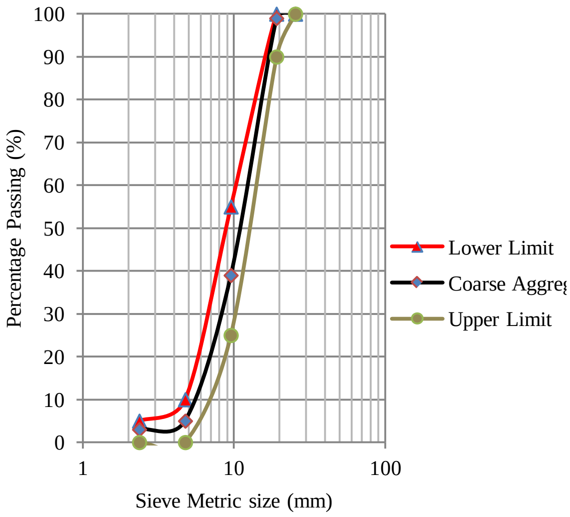


Figure 3: Particle size distribution curve of coarse aggregate.

2.1.4. Kerosene

The used kerosene was obtained from National Iranian Oil Refining and Distribution Company (NIORDC). Some properties of the kerosene used are summarized in Table 1.

Table 1: Properties of Kerosene used

Tests	Limit	Test method
Corrosion 3hr @ 100˚C	max 1	Astm D130
Density @ 15˚C (Kg/m3)	max 820	Astm D1298
Flash point (˚C)	min 38 ˚C	Astm D93
Total Sulphur (wt%)	max 0.15	Astm D1266

2.2. Specimen preparation and testing

A total number of 264 standard 150 × 150 × 150 mm^3 concrete cubes were prepared. The British Standard BS 1881: Part 125: 1986 [11] was used to produce the concrete mix and the proportion design were conducted in accordance with the ACI 211.1-09 guidelines [15].

To produce kerosene contaminated sand (KCS), fresh uncontaminated sand was contaminated with kerosene 0.5, 1, 2, 4, 6 and 8% (by weight). The resulting KCS was air-dried for about five days to allow proper reaction of the mixture and simulate the kerosene spill environment [4]. Table 2 shows the concrete mix proportions used in this study.

A rotary mixer was applied to produce a homogenous freshly mixed concrete. The mix was poured in standard steel cubic molds. In order to remove trapped air from the poured concrete, vibrating table was used. Afterwards, the top surfaces of the concrete specimens were smoothly troweled and leveled. The concrete cubes were removed from the molds after 24 hours. The specimens were subjected to three exposure zones including CPW, tidal and sea water, 84 samples for each exposure condition. 12 samples of uncontaminated specimens were immersed in kerosene, separately. The compressive strength tests of the specimens were conducted after 3, 7, 14 and 28 days and the clean sands specimens which immersed in CPW were used as control specimen.

Table 2: Mix proportion

Sample contamination (%)	Materials (kg/m3)					
	Cement	Water	Aggregate			Kerosene
			Fine	Coarse		
				10 mm	20 mm	
0	315	190	840	515	515	0
0.5	315	190	840	515	515	4.2
1	315	190	840	515	515	8.4
2	315	190	840	515	515	16.8
4	315	190	840	515	515	33.6
6	315	190	840	515	515	50.4
8	315	190	840	515	515	67.2

3. Results and discussion

Necessary standard cubic specimens were produced to evaluate the effect of kerosene impacted sand on the compressive strength of concrete in different exposure conditions. The results of the experimental program are shown in Figures. 4-7.

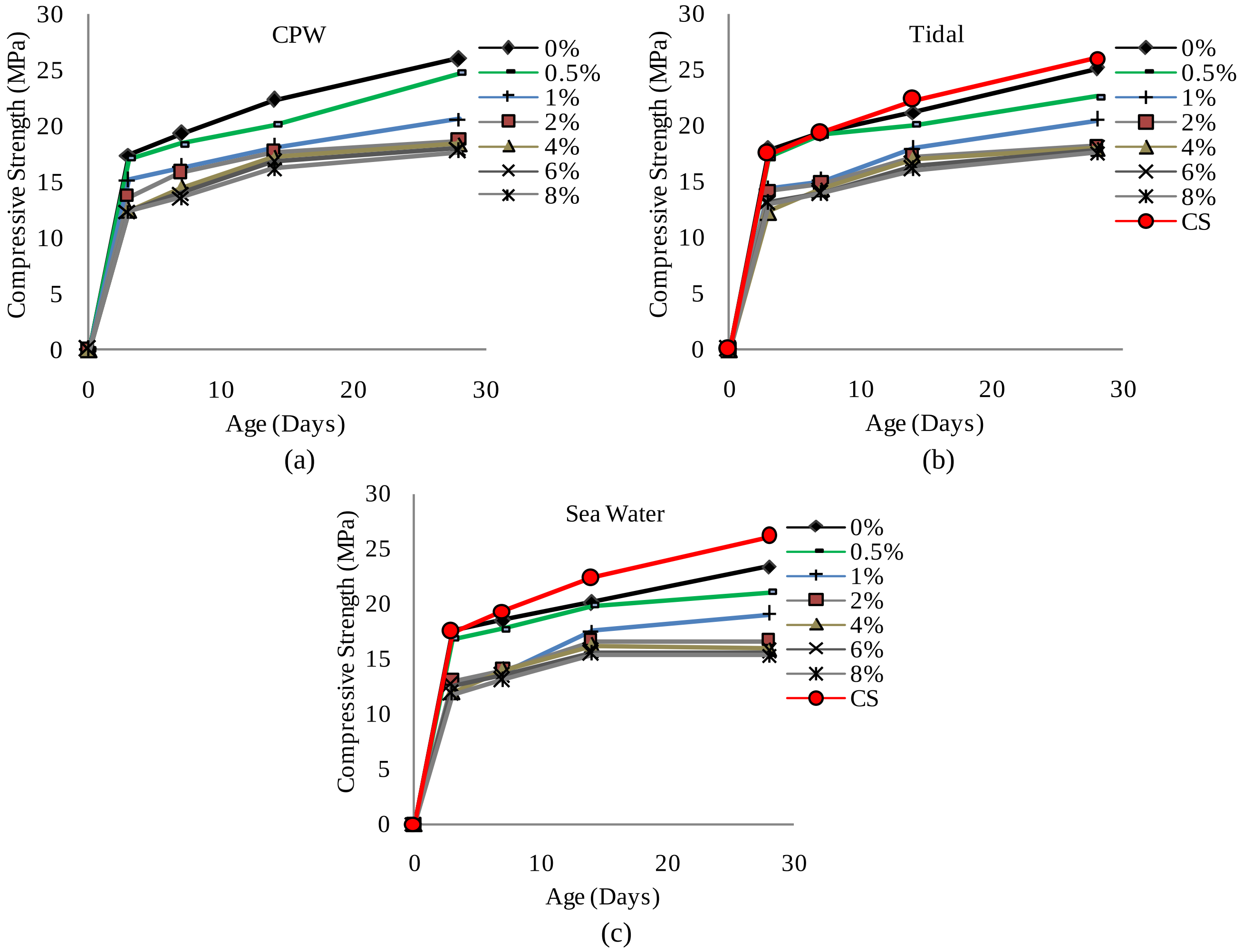


Figure 4: Compressive strength development of KCS concrete in different exposure conditions, a) CPW, b) Tidal, c) Sea water. (CS stands for control specimen)

In Figure 4 the average compressive strength of specimens are presented separately for each exposure condition. The average compressive strength value was determined based on three identical specimens tested on the same day. It is indicated from this figure that, the increase in the percentage of kerosene in all the exposure conditions resulted in decreased compressive strength of specimens and contaminated sand would adversely affect the compressive strength of concrete. Although the maximum reduction was obtained at 8% contamination, but the results of 2, 4 and 6% were so nearer to that. For specimens by 0.5% contamination strength reduction was less significant, about 5% reduction in comparison to control specimen in CPW.
The results of CS in Figures 4b and 4c are referred to control specimens. As mentioned earlier, control specimens are uncontaminated samples which were submerged in CPW. The specimens that were subjected to CPW achieved higher compressive strength than those were subjected to tidal and sea water.
In order to have a better comparison, the results of KCS concrete specimens in three exposure conditions are presented at 3, 7, 14 and 28 days in Figure 5. For the specimens at 3 and 7 days, the nearly similar profiles are shown for all exposure zones. In the cases of 14 and 28 days specimens, with increasing sample age, the compressive strength difference of samples in various zones increased. The results of 28 days samples of Figure. 5d show that, the minimum compressive strength is related to those samples which were immersed in sea water.

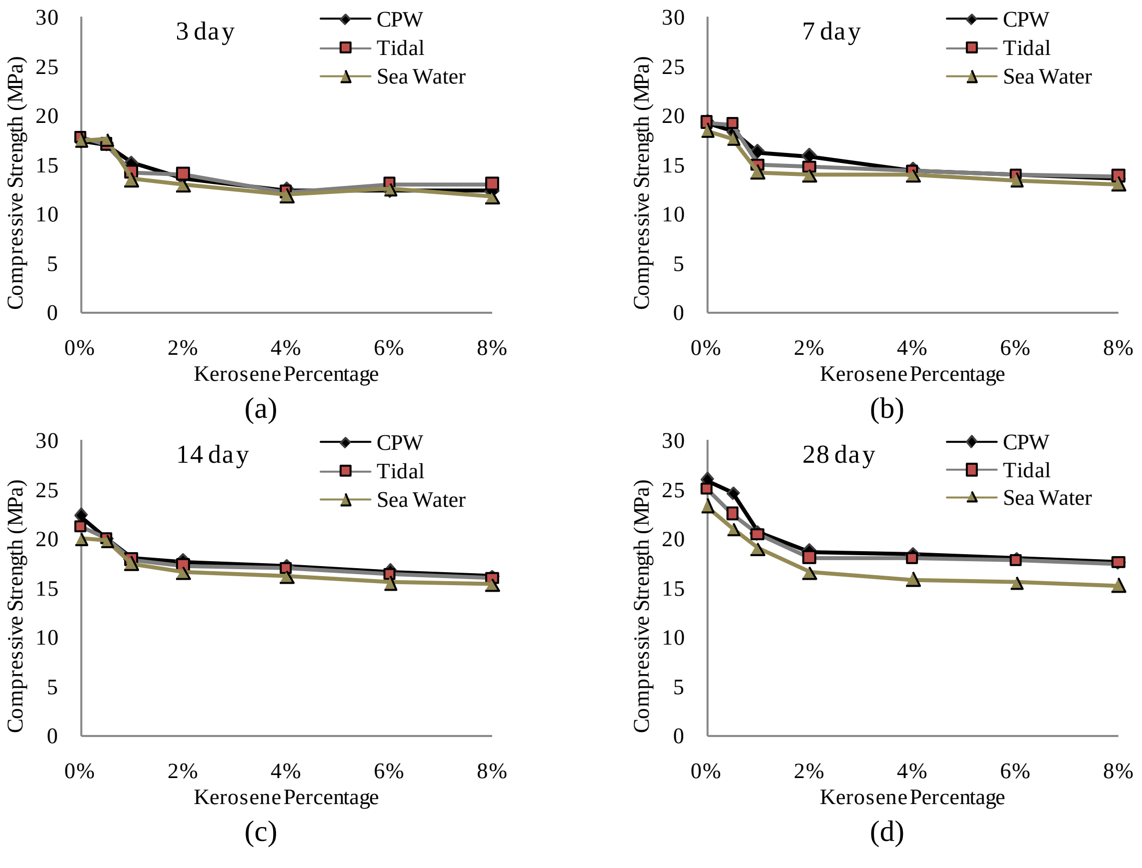


Figure 5: Compressive strength of KCS concrete in different exposure conditions, a) at 3 days, b) at 7 days, c) at 14 days and d) at 28 days.

Figure 6 shows the percent reduction of compressive strength for the contaminated specimens relative to the control specimen at 28 days. The percent reduction has been calculated using the following equation:

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

As it is shown in Figure 6, the highest obtained reduction in the concrete compressive strength was about 41.1% for the specimens contaminated with 8% kerosene and submerged in sea water. With increasing kerosene percentage of sand, the percent reductions of compressive strength of specimens subjected to CPW and tidal environment become closer. Therefore, the percent reductions of 2% contaminated samples were 27.9 and 30.3% for CPW and tidal, respectively, while the corresponding values for 8% contaminated samples were 32.1 and 32.5%. The failure modes of the tested cubes were shown in Figure 7. From observations of this figure it is indicated that the tested specimens failed in a regular crushing manner.

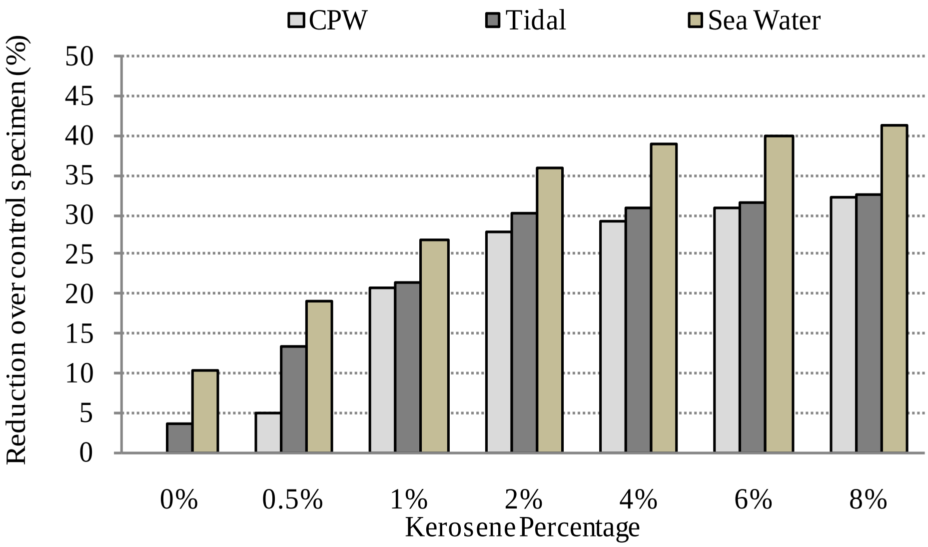
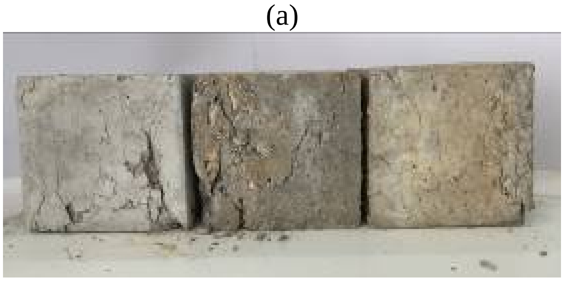


Figure 6: Percent reduction in compressive strength over the control specimen in different exposure conditions at 28 days.

(a)



(b)

(c)

Figure 7: Failure mode of the tested specimens in different exposure conditions (CPW, tidal and sea water, respectively from left to right) at 28 days (a) uncontaminated specimens, (b) specimens contaminated with 0.5% crude oil, (c) specimens contaminated with 2% crude oil.

The results of 12 uncontaminated samples which were submerged in kerosene and CPW are presented in Figure 8. For specimens submerged in kerosene, about 3% reduction in the compressive strength is appeared. This slight reduction is not significant and shows that immersing of concrete in kerosene does not have a negative effect on its compressive strength.

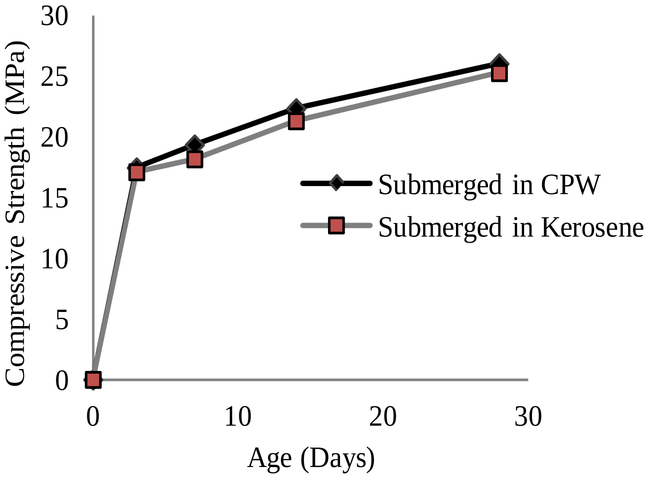


Figure 8: Compressive strength development of uncontaminated specimens submerged in CPW and kerosene.

Conclusion

This study focused on the effect of kerosene impacted sand on compressive strength of concrete in various exposure conditions. The obtained results confirm that:

1- The compressive strength of specimens were reduced by using KCS in concrete mix.

2- The exposure condition is one of the most important factors that must be considered carefully in service life design models for concrete structures.

3- In all the studied exposure conditions, the significant compressive strength reduction value was obtained at 2% contamination. By further increasing the contamination percent to 4, 6 and 8%, a slight reduction has been observed.

4- The highest reduction value in the concrete compressive strength was 41.1% for the specimens contaminated with 8% kerosene and immersed in sea water.

5- At initial days of concrete life, i.e. until the first 7 days, approximately the same results were revealed for all specimens in the all exposure zones. With increasing samples age, due to the special conditions of the tidal environment and sea water, the compressive strength of samples subjected to these exposure zones decreased.

6- The 28-day compressive strength of concrete in various exposure conditions follows the order of:

$$f_{c\text{-}CPW} > f_{c\text{-}Tidal} > f_{c\text{-}Sea\ water}$$

7- With increasing the percentage of kerosene contamination, the compressive strengths of samples subjected to CPW and tidal become closer.

8- After 24 hours of concreting, subjecting concrete to kerosene soaked environment is not significant.

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