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Review

Effect of Crude Oil Impacted Sand on compressive strength of concrete

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ABSTRACT

Effects of Crude Oil Impacted Sand (COIS) on the compressive strength of concrete was examined. Concrete mix, 1:1.8:2.7 was designed for all specimens with w/c of 0.5. Crude oil (2.5%, 5%, 10%, 15%, 20% and 25%) by weight of sand was used to contaminate sand for the preparation of COIS concrete. 147, 100 mm concrete cubes (21 control and 126 contaminated samples) were produced. The cubes were cured and the compressive strengths determined at ages 3, 7, 14, 28, 56, 84, and 168 days. COIS concrete samples showed slow rate of strength gain, and strength reduction compared with the control samples. A 18–90% compressive strength was lost due to 2.5–25% crude oil contamination, respectively.

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1. Introduction

Over the past two decades, the amount of hydrocarbon contamination of soil and the environment has continually increased, and presently it constitutes a significant fraction of waste materials in the environment. Some major sources of hydrocarbon contamination are oil spill, leaking of petroleum from underground storage tanks, oil pipe vandalisation, drilling, treatment activities for exploration and production of hydrocarbons, and hydrocarbon waste disposed from industries.

However, some waste can be used as chemical admixture and additives, which can alter and enhance selected properties of fresh and hardened concrete [1]. This can also assist in remediation of contaminated soil [2]. The successful use of Crude Oil Impacted Sand (COIS) in concrete depends on the required properties of the end product.

In general, compressive strength is considered most important property and the quality of concrete is often judged by its strength. The compressive strength of concrete depends on the properties of its ingredients, the proportion of mix, the method of compaction,

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the presence of contaminants and their degree, and other controls during placing and curing.

One very important factor that affects the compressive strength is contaminant and their degree. The ingredients of concrete are naturally contaminated and by man's activities but the extent or degree of contamination may differ from the ingredient source. The presence of contaminant in large degree in aggregates does not only affect the appearance of concrete (in terms of colour and smell) but also the strength developed by the concrete [3]. The effect of crude oil on the compressive strength of concrete when used as the curing medium had been considered by some authors [4–6], this paper, however, focuses on crude oil as a contaminant of fine aggregate and investigated the effect it has on the compressive strength of ordinary Portland cement concrete. This actually modeled the condition in the Niger Delta area of Nigeria where oil spillage is a regular occurrence contaminating soil and water. Many oil spill incidents had occurred in the past [7] and persist till date due to pipeline vandalisms. In some areas, it may be difficult to obtain sufficient quantities of uncontaminated aggregates but contaminated aggregates are available. Therefore, the occasional use of contaminated aggregates for construction purposes, particularly by local contractors, has to be considered. This forms the basis for this study.

2. Materials and methods

2.1. Materials

2.1.1. Cement

The cement used for the investigation was the Ordinary Portland Cement [8] and it had the properties to 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 [9].

2.1.3. Aggregates

The coarse aggregate used had a maximum size of 10 mm [10]. Fine aggregate was natural sand obtained in Ibadan, Oyo state. Both the fine and coarse aggregates were air dried to obtain saturated surface dry condition to ensure that water/cement ratio is not affected. Coarse and fine aggregates conform to BS 882 [11] specification. In this study, sieve analysis was initially carried out to obtain the particle grading curve of fine aggregate and its percentage passing 600 μm sieve for concrete mix design. Sieve analyses for the aggregates were conducted in accordance to BS 812 [12].

2.1.4. Crude oil

The crude oil was obtained from Bomu oil field in Gokana LGA of Rivers state, Nigeria. It has API gravity of 11.43, specific gravity of 0.99, density of 62 lbs/cuft and viscosity at 30 °C of 4.8 centipoise.

2.2. Methods

2.2.1. Preparation of sample

Soil samples for preliminary analysis were obtained from three different contaminated sites; viz: Bomu, B-Dere, and Bodo city of Gokana LGA of Cross Rivers State in Nigeria. The Total Petroleum Hydrocarbon (TPH) in the samples was determined using gravimetry, following saponification in methanolic-KOH, extraction by n-Hexane, and separation via liquid chromatography, to know the crude oil percentages in the contaminated sand samples. In addition, the residual dry sands were graded to serve as guide for the choice of sand for the main experiment. To make the COIS fresh uncontaminated sand similar in grade to sands of the contaminated sites was contaminated with crude oil at 2.5%, 5%, 10%, 15%,

Table 1
Mix proportion.

Sample contamination (%)	Materials (kg/m^3)				
	Cement	Water	Aggregate		Crude oil
			Fine	Coarse	
0	400	200	720	1080	Nil
2.5	400	200	720	1080	18
5.0	400	200	720	1080	36
10.0	400	200	720	1080	72
15.0	400	200	720	1080	108
20.0	400	200	720	1080	144
25.0	400	200	720	1080	180

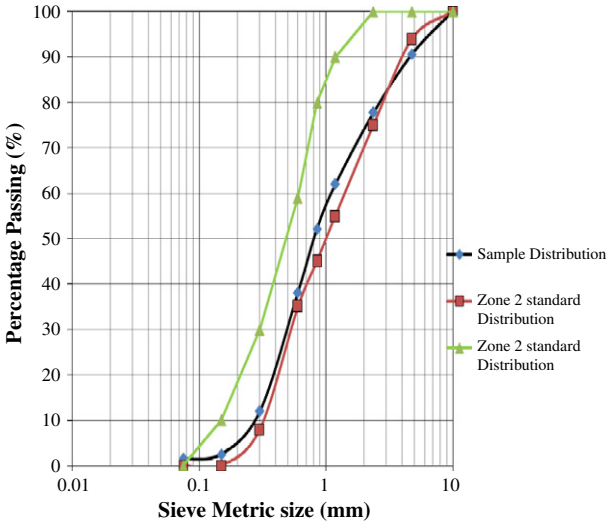

Fig. 1. Particle size distribution curve of fine aggregate.

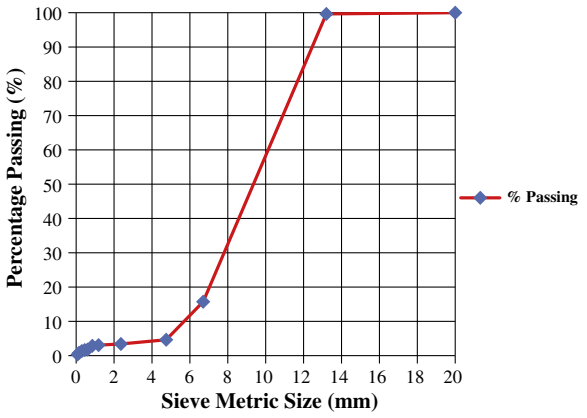

Fig. 2. Particle size distribution curve of coarse aggregate.

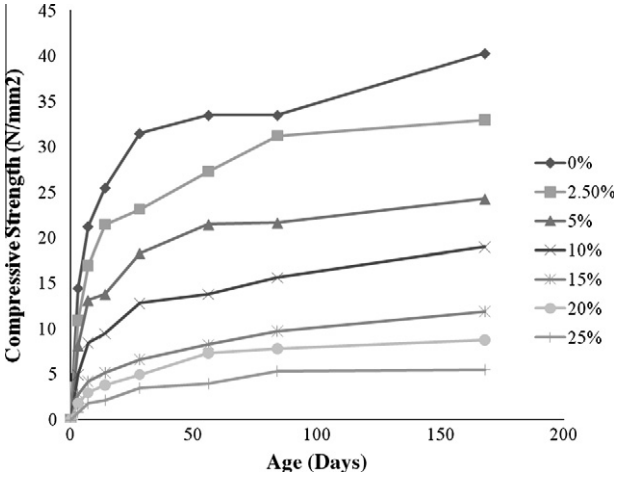

Fig. 3. Compressive strength development of concrete.

20% and 25% by the weight of sand. The resulting COIS was air-dried for about five days to allow proper reaction of the mixture and simulate the oil spill environment.

2.2.2. Concrete compressive strength test

The British method of concrete design [13,14] was used to produce a concrete mix ratio 1:1.8:2.7 at water cement ratio of 0.5 (refer to Table 1), for casting the concrete cubes. The mix was designed to achieve a nominal 28 days concrete compressive strength of 30 N/mm^2.

The cubes produced were of size 100 × 100 × 100 mm. The filling of the mould was in three layers and were manually compacted using 16 mm diameter metal rod at 25 strokes per layer [15]. Following this, 147 concrete cubes comprised of 21 controls and 126 crude oil contaminated specimens were produced. The cubes were demoulded after 24 h of casting and cured in a water tank [16]. The compressive strength gained was observed at ages 3, 7, 14, 28, 56, 84, and 168 days [17].

3. Results and discussion

3.1. Sieve analyses

Figs. 1 and 2 show the particle size distribution of the coarse and fine aggregates, respectively. From the particle size distribution curve of the fine aggregate, it was deduced that the fine aggregate falls in zone 2 consisting of 12% fine, 65% medium and 23% coarse sand. It possesses coefficient of uniformity (C_u) of 4.3 and a coefficient of curvature (C_c) of 0.74 which shows that the fine aggregate is well graded, similar to the soil of the oil spill sites and conforms to BS 812: Part 103.

3.2. Compressive strength of concrete cubes

The compressive strength test displayed in Fig. 3 shows that crude oil has effect on the compressive strength of concrete, as established by previous researchers [4–6]. The values of the control maintained a consistent increase in compressive strength as the curing age increases. This is not surprising as the strength of cement-based materials cured in water with no contamination increases with age. The COIS concrete also increased but at low strength development. The difference in results may be attributed to effect of chemical reaction taking place due to the presence of crude oil in the concrete cubes. The reduction in strength can be related to the varying percentages of crude oil contamination in the concrete, which may lead to loss of water content/moisture and preventing absorption of water by the concrete cube when cured in water. This occurrence has effect on the hydration of cement in the concrete cubes. The contamination of fine aggregate with crude oil which forms part of the microstructure of the matrix of concrete may have caused dilation of the gel and weakening of

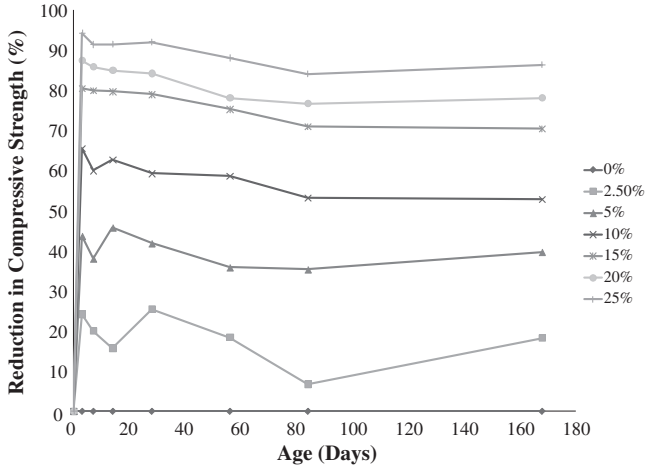

Fig. 4. Percentage reduction of concrete compressive strength.

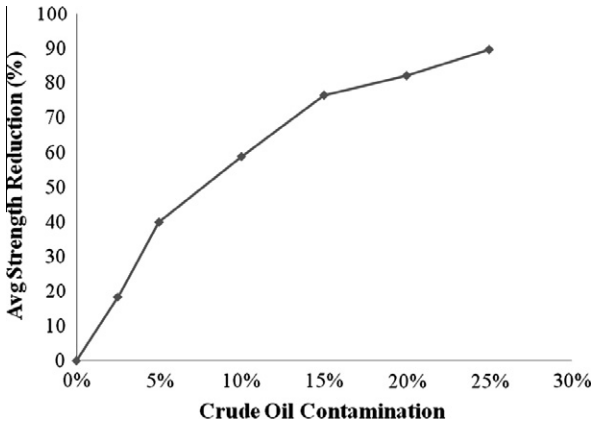

Fig. 5. Average percentage reduction in compressive strength of concrete.

the cohesive forces in the paste and hence low strength development of the concrete cubes cast with COIS.

The percentage reduction in compressive strength of COIS concrete in relation to the control, is expressed graphically in Fig. 4 to show the level of strength loss. The average of the percentage strength reduction indicates that about 18% of the strength will be lost when the soil is contaminated with 2.5% crude oil while almost 90% of the strength is lost due to 25% contamination (refer to Fig. 5). The strength reduction here is higher than when concrete is soaked in crude oil medium [5,6]. Thus sand containing more than 10% crude oil by weight of the sand will give a concrete with less than 50% of the expected strength of uncontaminated concrete and may not be put to any use particularly where strength is of necessity. However, with less than 5% contamination efforts could be made to improve the strength or the COIS concrete used in structures of low strength requirement.

4. Conclusion

The reduction of compressive strength of concrete by the presence of COIS is a function of the concentration of the crude oil in the sand. The higher the concentration, the higher the strength reduction.

The use of COIS as fine aggregate of concrete has more serious effect on its compressive strength compared with concrete cured in crude oil media.

Sands containing more than 5% crude oil contamination reduce compressive strength of the concrete more than 50%.

A design mix is required using 5% COIS to achieve the required strength while crude oil contamination between 5% and 10% should be considered for low strength concrete like Sandcrete block.

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References

[1] Bilal SH, Ahmad AR, Mutassem E. Effect of used engine oil on properties of fresh and harden concrete. Department of civil and environmental engineering, American University of Beirut. Constr Build Mater 2003; 17:311–8.
[2] Taylor BM. Bioremediation of hydrocarbon contaminated Soil. ECSOL Limited; 2007.

[3] British Cement Association. Computer aided learning for concrete. Version 2.3; 2001.
[4] Onabolu OA. Some properties of crude oil soaked concrete exposure at ambient temperature. ACI Mater J 1989:150–8.
[5] Ramzi BA, Azad AM. Compressive and tensile strength of concrete loaded and soaked in crude oil. Eng J Univ Qatar 2000;13.
[6] Ejeh SP, Uche OAU. Effect of crude oil spill on compressive strength of concrete materials. J Appl Sci Res 2009:1756–61.
[7] Badejo OT, Nwilo PC. Management of oil spill dispersal along the Nigerian Coasta areas. Department of surveying and geoinformatics, University of Lagos; 2004. p. 1.
[8] British Standards Institution. BS 12. Specification for ordinary and rapid-hardening Portland cement. London; 1978.
[9] British Standards Institution. BS 3148. Methods of test of water for making concrete. London; 1980.
[10] British Standards Institution. BS 1881: Part 108. Method for making test cubes from fresh concrete. London; 1983.
[11] British Standard Institution. BS 882. Aggregates from natural sources for concrete. London; 1983.
[12] British Standards Institution. BS 812: Part 103. Method of determination of particle size distribution. London; 1989.
[13] Teychenné DC, Franklin RE, Erntroy HC. DOE (BRE/DOE). Design of normal concrete mixes. Department of Environment. UK: Building Research Establishment; 1975 [revised Teychenné, Franklin, and Hobbs, 1988].
[14] Day KW. Concrete mix design, quality control and specification. 2nd ed. E & FN Spon; 1992.
[15] British Standard Institution. BS 1881: Part 1. Method for making test cubes from fresh concrete. London; 1983.
[16] British Standards Institution. BS 1881: Part 111. Method of normal curing of test specimens (20 °C method). London; 1983.
[17] British Standards Institution. BS 1881: Part 116. Method for determination of compressive strength of concrete cubes. London; 1983.