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Comparative Analysis of the Effect of Crude Oil and Water on the Compressive Strength of Concrete and Sandcrete Blocks

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ABSTRACT
Concrete and sandcrete, which are the most common construction materials, will also lose their strength and resistance to weather because of the exposure of crude oil in the polluted locations. The current article gives an analysis of the impact of crude oil and water on the compressive strength of concrete and sandcrete block. The experiment has looked at the effects of crude oil contamination and curing on the strength of varying percentages of mix. In potable water, and crude oil concrete samples (1:1.5:3, 1:2:4, and 1:3:6) and sandcrete blocks (1:6, 1:8, and 1:10) were cast and cured. At 28 days in water concrete compressive strengths were 41.0 N/mm 2, 48.5 N/mm 2, and 28.5 N/mm 2 whereas in crude oil compressive strengths were 32.0 N/mm 2, 35.0 N/mm 2, and 19.5 N/mm 2. All blends lost 20.77, 25.77 and 31.57 percentage strengths after 28 days. The cured sandcrete mixtures in crude oil contained 5.16 N/mm 2, and 1.80 N/mm 2 and 1.60 N/mm 2 as opposed to 7.33 N/mm 2, 3.20 N/mm 2, and 2.80 N/mm 2 in water, which led to a strength decrease of 43%. These findings help prove that crude oil postpones cement hydration and undermines bonding. Crude oil must not be used in the curing and constructing of buildings in oil-polluted areas. At oilfields, the data is useful in structural design and resistance.
Keywords: Compressive strength, Concrete, Sandcrete, Crude oil and Water

I. INTRODUCTION

Course aggregate is crushed, granular material (sand) that forms the building material of a composite material, concrete. A smaller particle known as aggregate is addicted to coarse aggregate and cement or another harder material known as cement keeps them together. Chen et al.[1]. Due to its simplicity, durability and widespread use, concrete is the kind of building material to be used in any building construction project in any corner of the world. Crude oil or petroleum which is a naturally occurring liquid may be used to make fuels, lubricating oils, asphalt and other useful items. Carbon and hydrogen are the main elements of this hydrocarbon and trace elements of sulphur, nitrogen and oxygen complete the composition [2]. The sulphurous element of any sort of crude oil can assault concrete. Research indicates that sandcrete blocks are precaster masonry blocks which when assembled and cemented can be used to construct different types of walls such as load bearing, enclosed and backup walls. In a research work carried out by Ali and Faris [3], the effect of various forms of oil on compressive and tensile strengths of high performance concrete were studied. The findings were drawn against the regular strength concrete. After a water curing period of 28 days, there was the use of four exposure periods which included 30, 60, 90 and 120 days of every specimen and liquid. Casts of reference specimens were placed in water throughout the entire test period to enable us compare them. The test results showed that compared to the usual strength concrete (NSC), high performance concrete (HPC) also had a reduced loss in the mechanical properties (compressive and splitting tensile strengths) in the presence of oil. Roughly 10% was the disparity. In addition, the compressive and splitting tensile strength of HPC and NSC declined relative to the drop in the viscosity of oil throughout the entire exposure time. Osuji and Nwankwo [4] investigated the impact of the crude oil pollution on the compressive strength of concrete. Due to the fact that crude oil pollutes the contents of concrete, the properties of concrete may significantly differ in the crude oil extraction sites. At the lab, we

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combined the concrete cubes of diverse degrees of contamination of crude oil to determine the influence of the contamination on the mechanical properties of the concrete. To obtain the contamination in concrete, the impure crude oil was added to the aggregate component of the test concrete. The scholars discovered that in concrete, crude oil leads to segregation when the linking between the constituents is disrupted. Therefore, the crude oil content in the fine aggregate will dictate the workability of the concrete; the more the crude oil content of the aggregate, the higher the workability of the concrete will be. Also, the contaminated cubes of concrete used were less compressive as compared to the control cubes. This is demonstrated beyond reasonable doubt that crude oil interferes with compressive strength of concrete during the manufacturing process. The presence of crude oil in the fine aggregate affects compressive strength negatively. It can be concluded that the most favorable level of crude oil contamination is one that is less than 0.3 percent in order to get normal compressive strength. Wasiu et al. [5] examined the effects of Crude Oil Impacted Sand (COIS) on positive compressive strength of concrete. All the specimens were cast in 1:1.8:2.7 concrete mixture with a water to cement ratio of 0.5. To ensure the COIS became concrete, crude oil was added to sand in concentrations of 2.5, 5, 10, 15, 20, and 25 percent weight of sand. The number of concrete cubes produced was 147 100 mm with 21 being controls and 126 being polluted samples. Compressive strength of the cubes was recorded when the cubes were 3,7, 14, 28, 56, 84 and168 days old. Due to 2.5-25% contamination of crude oil, the COIS concrete samples lost 1890% compressive strengths and strength gain rate was reduced compared to the control samples. Ojo and Ibe [6] compared the effects of exposure to crude oil and water on sandcrete blocks that had been cured over the period of 7, 14 and 28 days. In their study, they found that using water to cure the specimens enabled a greater compressive strength and faster hydration than the use of crude oil. The cement was not fully hydrated because the oil coating blocked the water penetration. Comparing to blocks which were water-cured, the compressive strength loss could be up to 25 percent. They arrived at the conclusion that the crude oil contamination is a serious inhibitor of the performance of sandcrete materials. Adewuyi and Adegoke [7] examined the degradation of concrete in the crude oil-impacted areas. Compressive strength of a cube of concrete that was curing in water, crude oil and a mix of crude oil and water was measured after7,28, and 56 days. The results revealed that oil-coated cement particles gave poor interfacial transition zone, which was observed to be the case with polluted specimens. The reduction in strength was 15-35: compared to specimens that were water-cured. The research proposed the identification of problems at early stages and correction in building areas polluted with oil. Nwachukwu and Okafor [8] experimented with sand concrete blocks to which various quantities of crude oil were added to the sand. The findings indicated that there was a direct relationship between percentage of crude oil and quantity of loss of strength. Blocks polluted with even 5 percent of the substance lost much of their strength when compared with samples of pure sand. Cement paste and sand particles could not connect with each other correctly because of the hydrophobic quality of the oil. The study indicates that the walls should ensure oil pollution is contained at less than 1 per cent. Isa et al. [9] conducted a study on the concrete submerged in different types of petroleum products, including kerosene, diesel, crude oil, etc. The research established that the compressive strength declined when the cement matrix was in prolonged contact to oil, which caused a chemical degradation of the cement. Concrete cured in water always attained the highest strength values. The results confirmed earlier speculations that hydrocarbons reduce the strength enhancing calcium silicate hydrates. This points out the vulnerability of concrete in the petroleum-rich areas. Oyelami and Aluko [10] tested sandcrete blocks made of river sand contaminated with crude oil in terms of compressive behaviour. They reported that hydration was not distributed uniformly, bonding was weak and porosity increased due to oil contamination. The compressive strength of oil-impacted sandcrete reduced to 2.5 N/mm 2 after 28 days, whereas clean sandcrete had 3.8 N/mm 2 compressive strength. The study conducted may help restore partial strength through remediation and washing of contaminated sand. Nuhu and Garba [11] compared the influences of water and crude oil as curing medium on the concrete density and compressive strength. The strength of the samples that were cured in water strengthened with time whereas those that were cured in crude oil strengthened at a lower rate and also were of low densities. The loss of strength ranged between 10 and 28 percent as the days went on (28 days). The researchers believed that it was because of the covering of the oil, which was impermeable and reduced hydration that caused the loss. Their piece

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of advice was to avoid aggregates that were exposed to crude oil when constructing structures near oil plants. Eze and Onwuka [12] examined the microstructural changes in polluted concrete with oil. They applied scanning electron microscopy to discover that there were microcracks at the paste-aggregate interface as a result of dissolution of calcium hydroxide crystals introduced by the presence of crude oil. The compressive strength of the contaminated concrete had reduced by a quarter of that of the water-cured control after 28 days. According to the research, crude oil accelerates the disintegration and structural instability of the surface. Hassan and Udo [13] studied the behavior of concrete in the presence of different water, saltwater, and crude oil. The findings showed that the compressive strength was highest on the specimens that were cured in water and seawater, and the lowest on the specimens that were cured in crude oil. Hydrocarbons and hydrated cement substances chemically reacted which caused loss of strength, which increased over time. According to the authors, concrete in petroleum plants require protective coating. Okechukwu et al. [14] carried out a study to compare the durability of sandcrete blocks which they exposed to crude oil and salt water. Due to the formation of weak carbonaceous coating around cement particles the study demonstrated that the exposure to crude oil led to a greater strength loss than when exposed to salty water. The strength of blocks that were in salt water (3.7 N/mm 2) was considerably different to the strength of blocks that were in crude oil (2.3 N/mm 2) after 28 days. They reached the conclusion that durability is under a significant influence of oil pollution. Essentially, Balogun and Akintola [15] explored the soil properties at the Niger Delta and the interactions of crude oil and water with reinforced concrete elements. They found out that corrosion rate and compressive strength of steel increased and reduced respectively in the presence of oil. The compressive strength fell by 30 per cent after being immersed in crude oil in 60 days. In the study, surface waterproofing and regular inspection were recommended in case of oil-affected structures. Because of the percentage of sulphur content that is either equal or higher than 10 percent, the Nigerian crude oil is normally categorized as either sweet or sour crude [16]. Most of the oil spills occurring in the Niger delta region are of crude nature, and this presents a risk to aquatic life, humans, and cement-based products. This is regardless of the fact that the content of sulphur is usually removed in the refining process, yet it still needs further processing. The proposed research seeks to address the gap in our knowledge on the degree to which the leakage of the crude oil decreased the compressive strength of sandcrete and concrete blocks.

II. MATERIALS AND METHOD

2.1 Materials

2.1.1 Cement: The Dangote 3x, 42.5 grade, Ordinary Portland Cement was sourced from the Ibese factory.

2.1.2 Aggregate: Aggregate, both fine and coarse, were used. As a coarse aggregate, we use granite that is no larger than 12mm (1/2 inch), and as a fine aggregate, we use Okhuahe river sand. The University of Benin's Civil Engineering laboratory received both for use in their experiments. Throughout the sieve analysis procedure, we made care to comply with BS 812-1.

2.1.3 Crude Oil: The crude oil that was used was sourced from oil spills in the Niger Delta area of Delta State, Nigeria.

2.1.4 Water: The University of Benin's School of Engineering used a borehole to supply water for this project.

2.2 Method

Four approaches were taken:

- After the concrete had been cast in three different mix ratios (1: 1.5: 3, 1: 2: 4 and 1: 3: 6), they were cured by means of portable water.
- Portable water and crude oil were used to cast three various ratios of concrete in mix 1:1.5:3, 1:2:4 and 1:3: 6.
- The samples were then cured using the portable water after casting sandcrete with three ratios (1:6, 1:8 and 1:10).
- Cast sandcrete in three proportions (1:6, 1:8, and 1: 10) with the help of portable water and curing with crude oil.

2.2.1 Preparation of concrete samples

The concrete cube test used three varying mix ratios in three volumes namely: 1:1.5:3, 1:2:4 and 1:3:6 using water-cement ratios of 0.5, 0.5 and 0.65 respectively. Cubes of concrete that were already made measured 150 mm x 150 mm x 150 mm. The new concrete was poured in 2 layers on pre-made moulds and pre-vibrated (20-30 seconds or 1-2 minutes) depending on the ratio of water to cement ratio and grade of concrete. The total number of cubes was 72 cubes with the batches producing 24 cubes each. Periods of 7, 14, 21, or

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28 days, with different proportions of the mix, 36 cubes in water were used as a control and 36 cubes in crude oil as an experimental group were cured. The 2000 kN compressive machine was used in the test, the machine provided a constant load rate of 15 kN/s, which is in line with BS:1881-108 and BS:1881-116, 1983.

2.2.2 Preparation of sandcrete samples

The sandcrete cube test employed the use of three different proportions of sand and cement, each proportion being mixed with water-cement proportion, namely; 1:10, 1:6, and 1:8. The sandcrete cube material that is built is of 150 mm dimension on all sides. Once the two layer moulds were filled with the freshly mixed concrete, the compacting bar was applied to the mould crust to ensure that twenty-five strokes were uniformly distributed across the cross-section of the mould, compacting each of the layers. Every batch had six cubes, having a total of eighteen cubes, in all the three mix proportions. Each experimental mix ratio had three cubes which were cured in water to control. Cubes that were not cured in crude oil took 42 days. A compressive machine of 2000 kN was used in the test giving a steady load rate of 15 kN/s, in accordance with BS:1881-108 and BS:1881-116, 1983.

III. RESULTS AND DISCUSSION

Table 1 shows that the sulphur content of the crude oil was 0.3%w and is much above the 250 mg/l limit and starts killing cement-based products. The other problem is that the alkaline Portland cement reacts with the crude oil which is relatively acidic to neutralise the cement reducing the bonding capacity of the cement. The table 2 indicates the outcomes of the compressive strength tests performed to determine the curing in the concrete in the medium of portable water and crude oil. The mixes tested were 1:2:4, 1:3:6, and 1:1.5:3. Figures 1, 2 and 3 respectively give the graphical behaviour of the concrete. As the data shows, the compressive strength formation processes of the three different concrete mixes in water and crude oil curing conditions are growing at a steady rate between seven days to twenty-eight days curing, however the mixes in the crude oil curing condition have a rather low rate of strength formation. The mean compressive strength of the concrete occurred as 40N/mm2 in the 1:1.5:3 mix in water after 28 days of curing, and the medium of crude oil had a compressive strength of 32.0N/mm2 after 28 days of curing. The 1:2:4 mix had values of 48.5N/mm2 and 39N/mm 2, and the 1:3:6 mix had values of 28.5N/mm2 and 19.5N/mm 2 respectively.

Table 1: Properties of Nigeria Crude Oil [2]

S/N	Parameters	Magnitude
1	Specific gravity @150ºC	0.812
2	API gravity @ 150ºC	>35.00
3	Viscosity @ 21ºC	6.81
4	Sulphur content % by weight	0.30
5	Melting point of wax ºC	57
6	Acidity (mg KOH/g)	0.05
7	Wax content % by weight	7.0
8	Moisture content % by volume	0.40
9	Carbon residue % by weight	2.10

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Table 2: Compressive Strength of Both Media for The Three Mixes

Concrete Medium	Curing Medium	Compressive Strength (N/mm^2)			
		Curing Period			
		7Days	14Days	21Days	27Days
1:1.5:3	Water	28.50	31.00	37.00	41.00
	Crude Oil	25.00	26.00	28.50	32.00
1:2:4	Water	29.50	33.00	41.00	48.50
	Crude Oil	24.50	26.00	28.50	35.00
1:3:6	Water	19.50	21.50	24.50	28.50
	Crude Oil	14.00	16.00	17.00	19.50

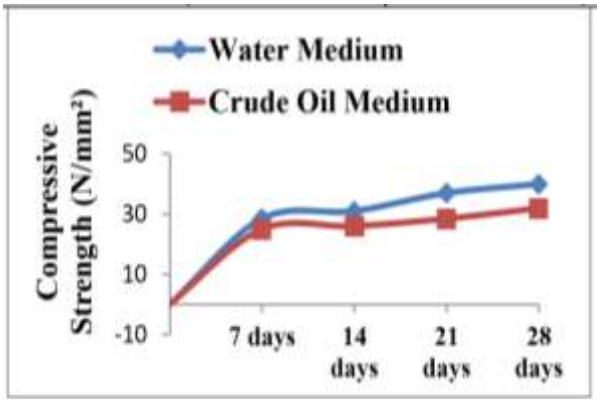

Figure 1: Rate of Development of Compressive Strength of Concrete for 1:2:4 Mix Design.

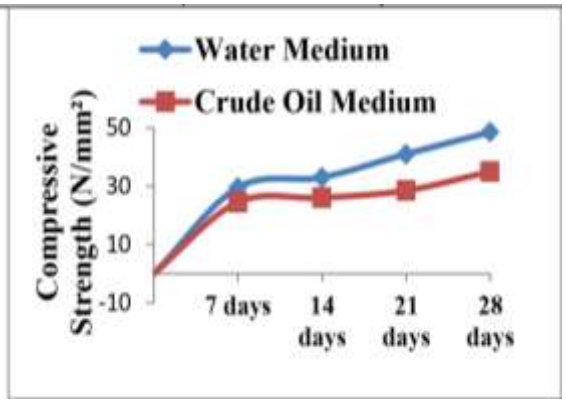

Figure 2: Rate of Development of Compressive Strength of Concrete for 1:1.5:3 Mix Design.

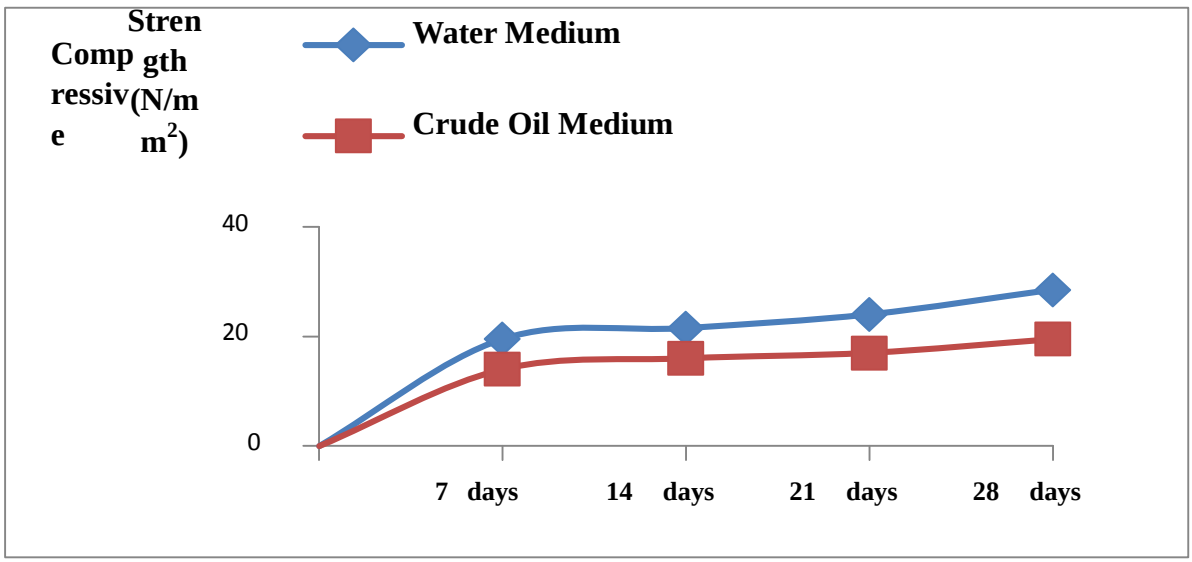

Figure 3: Rate of Development of Compressive Strength of Concrete for 1:3:6 Mix Design

The reason behind the decrease in compressive strength of the concrete cured in this medium is the chemical reactions that are taking place in the crude oil solution and not in the control medium (water). The reaction is brought about by the attack of the sulphate ions on the major components of the cement paste microstructure. The chemistry of sulphate attack is connected with an extensive web of interdependence of processes, reactions, and internal and external sources [17]. Concrete can experience a sequence of reactions when sulphate ions enter the material externally, and these reactions can include the gradual dissolution of calcium sulphate hydration (CS-H) phase and the gradual dissolution of portlandite (CH). In the second case, the rigidity of the

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hardened cement paste is lower as the ratio of calcium sulphate of this phase is lower, as it eliminates Ca2+ of the structure. Meanwhile, more chemicals, commonly referred to as ettringite, are formed as the sulphate dries. These new crystals occupying space cause volumetric tensions in the hardened material and the concrete is also damaged further because the paste which holds them together is being destroyed as the crystals keep on forming.

Table 3: Percentage Reduction in Compressive Strength for the three Different Concrete mixes considered.

Concrete Mix	**Percentage Reduction in Compressive Strength (%)**			
	Curing Period			
	7days	**14days**	**21days**	**28days**
1:1.5:3	12.18	16.13	22.97	20.00
1:2:4	16.79	21.21	30.48	25.77
1:3:6	25.64	30.23	30.61	31.57

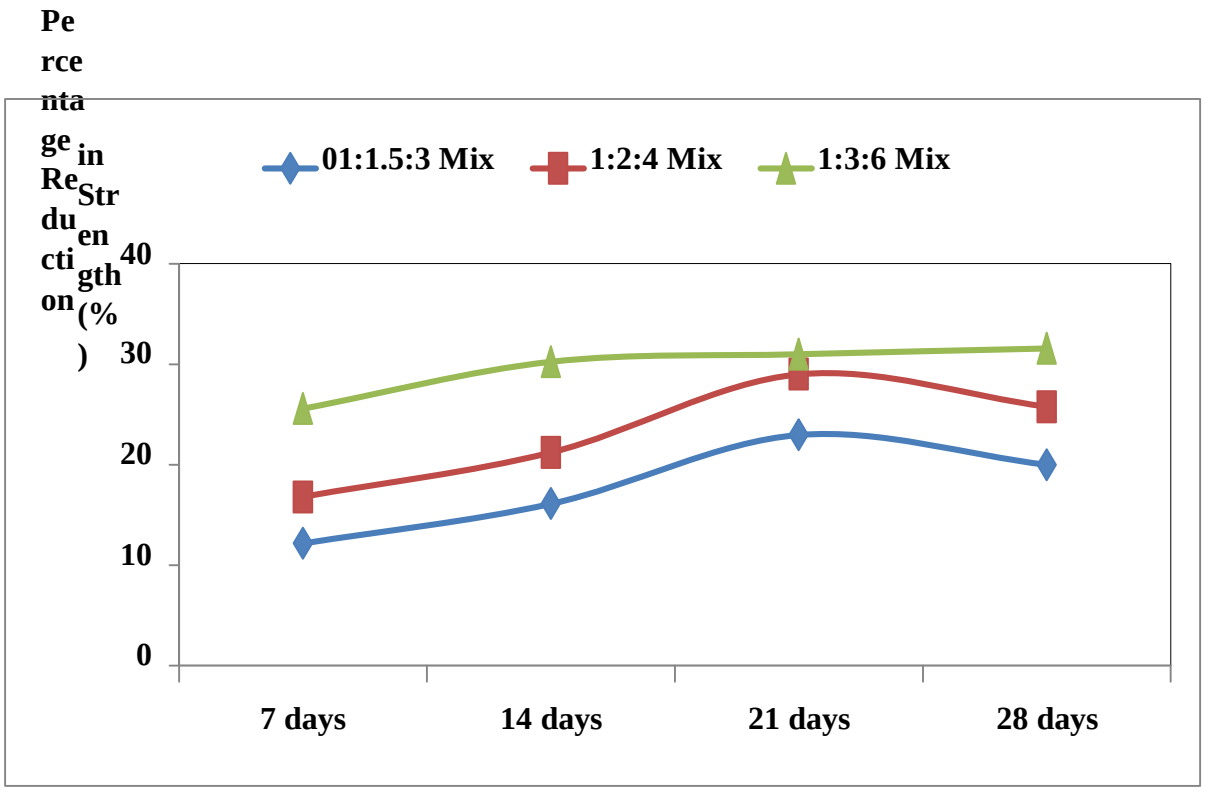

Figure 4: Percentage Reduction in Average Compressive Strength for the three Different mixes of Concrete considered

Figure 4 and table 3 represented the comparison of the three concrete mixes and the resulting increase or decrease (in average compressive strength) of these mixes in the form of percentages. Crude oil assaults the bond of concrete and consequently the cement-based material and this explains why mixes containing lesser concentrations of cement have an average compressive strength that is considerably less. The concrete in crude oil medium, once cured, might have had an unsuccessful strength development because of the gel dilatation and the low cohesive

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forces in the paste caused by the absorption of crude oil in concrete matrix micro structure. As per what Ejeh and Uche discovered, this is also referred to as the wetting weakening effect [2]. The conductivity and sulphur ion concentration among other chemical reactions can influence the aggressiveness of the crude oil medium on the strength of concrete. These reactions may change the composition of the paste and this causes conversion of the monosulfate phase to ettringite and thus loss of bond between the cement paste and the aggregates thereby lowering the overall strength of concrete. This information indicates that the aggregates (which are used to make the concrete) did not act as the major cause of the major reduction in the average compressive strength of the concrete as compared to that of the cement paste.

Table 4: Percentage Reduction in Compressive Strength of the Sandcrete mixes at 42 days.

Sandcrete Mix	Curing Medium	Compressive Stregth (N/mm^2)	Percentage Reduction in Strength (%)
1:6	Water	7.33	29.60
	Crude Oil	5.16	
1:8	Water	3.20	41.86
	Crude Oil	1.80	
1:10	Water	2.80	42.86
	Crude Oil	1.60	

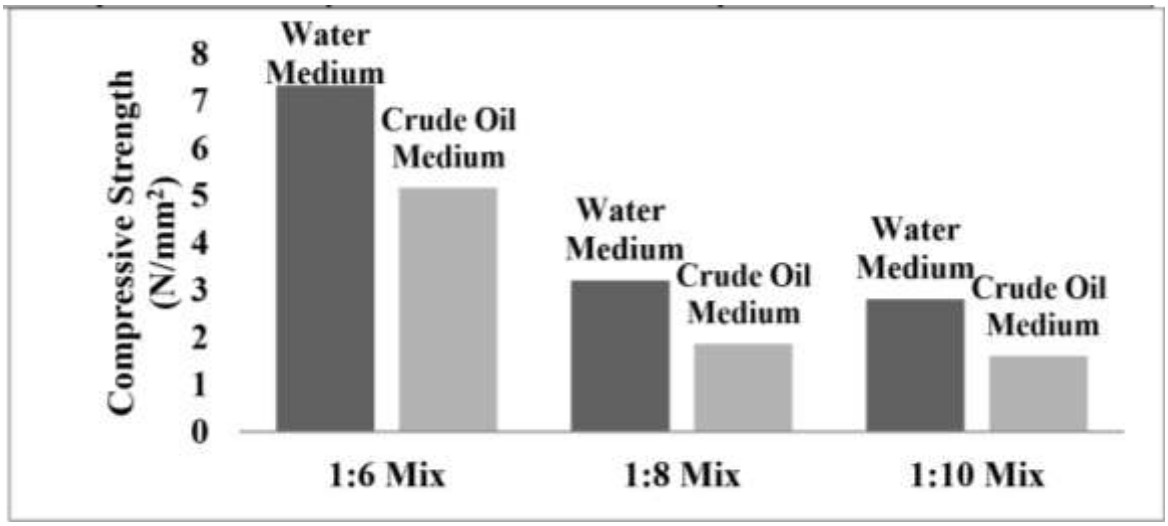

Figure 5: Compressive Strength of Sandcrete for both curing media and the three mixes Considered at 42days

The findings of the percentage change in compressive strength and average compressive strength of the different sandcrete mixes that have been subjected to the two mediums of cure are shown by figure 5 and table 4 respectively. The compressive strength of the sandcrete reduced with the increase in the ratio of the two curing media in the mix. The compressive strength of the samples at the different combinations was significantly low in the crude oil media compared to the control medium (water). The mean compressive strength of sandcrete cubes is lower since, as mentioned above, the inclusion of the attack sulphate element suppresses the formation of bonds among cement and fine aggregates.

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IV. CONCLUSION

The research was able to determine that crude oil contamination negatively impacts on the compressive behaviour of concrete and sandcrete blocks. Concrete specimens that were allowed to cure in crude oil experienced reduced development of strength as compared to the ones that were allowed to cure in water because of sulphate attack and interference with cement hydration process. The highest compressive strength measurement of 28-days of water-cured concrete was 48.5 N/mm 2 (1:2:4 mix), as opposed to 35 N/mm 2 of crude-oil-cured samples. Similarly, blocks that were dried in crude oil sandcrete registered as high as 43 percent less compressive strength compared to blocks dried in water. This was due to the reduction in strength caused by the fact that sulphur and acidic compounds in the crude oil reacts with calcium hydroxide and calcium silicate hydrates to form expansive ettringite which weakened the cement matrix. Paste cohesion and bond strength were also minimized by the so-called wetting-weakening effect of crude oil. It may be concluded that concrete and sandcrete buildings that get in contact with crude oil are subjected to gradual degradation and ought to be defended with non-porous surfaces, choice of inert binders or moving structural foundations out of the oil-affected areas to make the buildings durable.

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