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Effects of Oil Contaminated Water on the Compressive Strength of Concrete

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Abstract
Clean water is a vital constitute in the production of concrete for construction, apart from cement, coarse aggregate and fine aggregate. But, when the water is contaminated, it may have affect the compressive strength of the concrete. In crude oil producing host communities, a condition known as "oil contamination" often occurs when spills of crude oil pollute waterways, making them unsuitable for use in the production of concrete. In several building projects in the Niger Delta Region, particularly in Amassoma, Bayelsa State, the contaminated water was frequently utilized. The purpose of this study was to evaluate the impact of oil contamination on the compressive strength of concrete produced in the Niger Delta region in order to determine its acceptability for concrete manufacturing. After determining the physico-chemical characteristics of both treated and untreated water, the properties of the concrete that was produced were ascertained, including wet density and slump. The compressive strength after curing at 3, 7, 14, and 28 days were obtained. The findings indicated that both the treated and untreated water were acidic, but the untreated water had more iron (5.34 mg/L) than the treated water (0.53 mg/L). Concrete made with untreated water has a slightly higher compressive strength than concrete made with treated water. However, the concrete made from both fluids has compressive strengths greater than the 25 N/mm2 design strength. Furthermore, the new qualities were within acceptable bounds. We may conclude that oil pollution in the vicinity of Amassoma, Bayelsa State, enhances rather than decreases the compressive strength of concrete. This study suggests producing concrete in the same area using untreated water.

Keywords: Concrete, Compressive Strength, Oil Spillage, Niger Delta Region.

Introduction

Essentially, concrete is a composite material made of cement, water, fine aggregate, coarse aggregate and/or admixture. During the curing and hardening stages, concrete undergoes a chemical transition to produce a strong and long-lasting solid (Callister and Rethwisch, 2013). Concrete constituent materials are mixed thoroughly depending on the precise mix proportions used, most times, aggregates normally make up between 50% and 60% of the overall volume of the mix (Neville, 2011). The unparalleled significance of concrete in the building industry is demonstrated in its global consumption, which in most cases is almost double that of steel, wood, plastics, and aluminum (Mehta & Monteiro, 2006).

When concrete is used in construction, it is either used in its basic form or reinforced with steel to accomplish different design requirements, and that is due to its highly adaptable characteristics in achieving a range of strength levels suitable for diverse structural uses. Because of its exceptional durability, which ensures resistance to deterioration mechanisms like corrosion, decay, and fire, it is a crucial material for constructing long-lasting architectural structures, foundations, brick walls, bridges, and many other civil engineering infrastructures (Neville, 2011; Mehta & Monteiro, 2006). The wide and continuous use of concrete in the construction of buildings and infrastructure worldwide is largely due to its remarkable compressive strength and durability, which are essential qualities to satisfying the increasing demands of human progress and advancement in construction in the 21st century (Ajamu & Ige, 2015).

In Nigeria's oil and gas sector has grown rapidly, in the past 40 years, but unfortunately it has also caused serious environmental harm, particularly in the oil rich Niger Delta region. Frequent leaks of crude oil into bodies of water have seriously damaged the natural environment, particularly water supplies utilized in building activities (Ekpelu, 2019).One notable consequence of this environmental issue is the potential harm to the water quality and how it affects its utilization in the production of concrete for construction. Since water is a crucial part of concrete mixtures, oil pollution may drastically lower the concrete's compressive strength, which is a character necessary to ensure that the buildings can support loads (Owusu, 2017).

It is believed that oil pollution in mixing water has a negative impact on the workability and overall quality of concrete. Some arguments contend that the presence of iron oxide in crude oil might potentially facilitate the cement hydration process, as iron oxide is one of the four primary oxides present in cement (Neville, 2011). Nonetheless, the vast majority of scientific data suggests that the cementitious matrix in most concrete made with contaminated watre, may be negatively impacted by hydrocarbons and other chemical substances found in crude oil. However, this claim seem not to be well supported by empirical data, particularly in Nigeria and the Niger Delta region, where oil spillage is usually frequent. It is presumed that chemical interactions may alter the microstructure of hardened concrete, thereby increasing its porosity, and reducing its overall structural integrity. All of which may reduce the material's compressive strength and endurance of concrete (Hamid et al., 2018; Li et al., 2017).

Due to the increasing number of oil spill incidents recorded and the possibility of significant detrimental effects it may have on infrastructure in most oil-producing nations, the need for investigating the effects of oil-spill-contaminated water on the compressive strength of concrete is very crucial and is the focus of this study. In Nigeria's Niger Delta region, particularly in Bayelsa State, it is essential to guarantee the production of high-quality concrete for construction development. This requirement is made even more crucial by the fact that many construction sites in Bayelsa State, are presumed to be located below sea level and are very susceptible to environmental problems (Ekpelu, 2019). Consequently, thus study is aimed at investigating the effects of Oil contaminated water on the Compressive Strength of Concrete.

Materials and Methods

Portland cement, fine aggregate (sand), coarse aggregate (granite), water (treated and untreated water), and chemicals used to test the physicochemical properties of the water used were the materials used in this study. Dangote cement of grade 42.5N was obtained from a local market in Amassoma, Yenagoa, and complies with the specifications outlined in ASTM C150/C150M (2012). The fine aggregate used in this study was obtained from a commercial supplier in Amassoma and stored under suitable conditions. It is mainly composed of rounded particles, as Plate I illustrates. The sand has been cleaned by rivers and is devoid of harmful substances. The minimum and maximum particle sizes are 75 micrometers and 4.75 mm, respectively. The sand has a specific gravity of 2.6. The fine aggregate used for this study, satisfies ASTM C33/C33M standards.

Plate I: Fine Aggregate used

The coarse material utilized in this study was granite acquired from a local market in Yenagoa. It is an angular-shaped aggregate with a specific gravity of 2.65 and a maximum size of 19mm. It's a well-graded coarse aggregate that meets ASTMC33/33M.

Plate II: Coarse Aggregate used

This study employed two types of water: clean, treated water and untreated water tainted by an oil spill. The treated water used in this study, met the standards of ASTM C1602/C1602M and was utilized to mix and cure the concrete. In contrast, untreated, oil-contaminated water was only utilized for mixing. Niger Delta University's Chemistry Department investigated the physical and chemical parameters of both treated and untreated water samples used in this study.

Mix Design

For this study, the British Department of Environment's (DOE) technique for identifying concrete constituent materials was used to create the proportions of the concrete mix in this study. Table 1 displays the mix proportions employed in this investigation.

Table 1: Mix proportion for Concrete constituents

Mix	Cement (Kg/m3)	Water (Kg/m3)	Water/Cement ratio	Sand (Kg/m3)	Coarse (Kg/m3)
J1	6.0	3.14	0.52	15.14	18.87
J2	6.0	3.14	0.52	15.14	18.87

2.3 Wet Density

The concrete's wet density used in this study, was calculated using the method outlined in BS EN 12390-7 (2019). As a standard, the empty container was first weighed and designated as W1. The container containing the freshly mixed concrete was then weighed and designated as W2. Additionally, the container's capacity was measured. The wet density was then calculated using the following formula:

$$\text{Wet density} = \frac{W2-W1}{V}$$

Slump

To evaluate the workability of each concrete mix, slump tests were performed. According to the protocol described in BS EN 12350-2 (2019), three distinct batches were made, and a slump test was conducted for each batch used in the study. Based on how the concrete behaved during testing, the results were divided into three categories: real slump, shear slump, and collapse (failed) slump.

Compressive Strength Test

Concrete sample testing was done in compliance with BS EN 12390-3 (2019). At curing ages of 3, 7, 14, and 28 days, concrete cube specimens of 100 × 100 × 100 mm were made and examined (Plate III). A total of twenty-four concrete cubes were tested for both treated and untreated water in three specimens for each curing time, in this study.

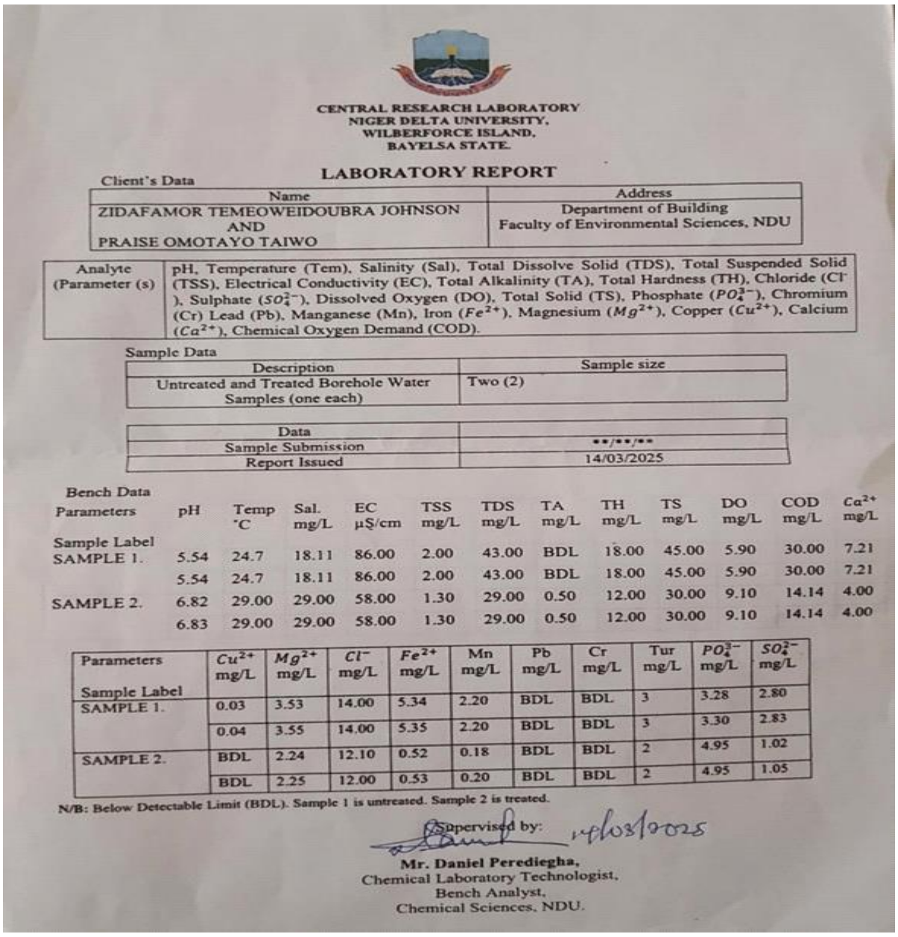
a b

Plate III: crushing of concrete specimen

Results and Discussion

Water Test Result of Specimen A and Specimen B

Below are the findings from the two water samples that were utilized to make concrete. With pH values of 5.54 for the untreated water and 6.82 for the treated water, the results show that both samples are rather acidic. There was no discernible heavy metal pollution since neither lead nor chromium were found. The iron level of the two samples differs significantly: the treated sample has just 0.52 mg/L of iron, whereas the untreated water has 5.34 mg/L (Plate V). This indicates that the untreated water has significantly greater iron content. According to Neville (2011), cement can contain up to 6% iron, inferring that the iron levels in untreated water from the Amassoma region may not considerably affect its appropriateness for use in concrete production.



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LABORATORY REPORT

Client's Data

Name	Address
ZIDAFAMOR TEMEOWEIDOUBRA JOHNSON AND PRAISE OMOTAYO TAIWO	Department of Building Faculty of Environmental Sciences, NDU

Analyte (Parameter (s)	pH, Temperature (Tem), Salinity (Sal), Total Dissolve Solid (TDS), Total Suspended Solid (TSS), Electrical Conductivity (EC), Total Alkalinity (TA), Total Hardness (TH), Chloride (Cl^-), Sulphate (SO_4^{2-}), Dissolved Oxygen (DO), Total Solid (TS), Phosphate (PO_4^{3-}), Chromium (Cr) Lead (Pb), Manganese (Mn), Iron (Fe^{2+}), Magnesium (Mg^{2+}), Copper (Cu^{2+}), Calcium (Ca^{2+}), Chemical Oxygen Demand (COD).

Sample Data

Description	Sample size
Untreated and Treated Borehole Water Samples (one each)	Two (2)

Data	
Sample Submission	**/**/**
Report Issued	14/03/2025

Bench Data

Parameters / Sample Label	pH	Temp °C	Sal. mg/L	EC µS/cm	TSS mg/L	TDS mg/L	TA mg/L	TH mg/L	TS mg/L	DO mg/L	COD mg/L	Ca^{2+} mg/L
SAMPLE 1.	5.54	24.7	18.11	86.00	2.00	43.00	BDL	18.00	45.00	5.90	30.00	7.21
	5.54	24.7	18.11	86.00	2.00	43.00	BDL	18.00	45.00	5.90	30.00	7.21
SAMPLE 2.	6.82	29.00	29.00	58.00	1.30	29.00	0.50	12.00	30.00	9.10	14.14	4.00
	6.83	29.00	29.00	58.00	1.30	29.00	0.50	12.00	30.00	9.10	14.14	4.00

Parameters / Sample Label	Cu^{2+} mg/L	Mg^{2+} mg/L	Cl^- mg/L	Fe^{2+} mg/L	Mn mg/L	Pb mg/L	Cr mg/L	Tur mg/L	PO_4^{3-} mg/L	SO_4^{2-} mg/L
SAMPLE 1.	0.03	3.53	14.00	5.34	2.20	BDL	BDL	3	3.28	2.80
	0.04	3.55	14.00	5.35	2.20	BDL	BDL	3	3.30	2.83
SAMPLE 2.	BDL	2.24	12.10	0.52	0.18	BDL	BDL	2	4.95	1.02
	BDL	2.25	12.00	0.53	0.20	BDL	BDL	2	4.95	1.05

N/B: Below Detectable Limit (BDL). Sample 1 is untreated. Sample 2 is treated.

Supervised by: 14/03/2025

Mr. Daniel Perediegha,
Chemical Laboratory Technologist,
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Plate IV: Test Result of the treated and untreated water samples

Wet Density

The wet density of concrete made with treated and untreated water is displayed in Table 4.1. It is evident that the wet densities of the treated and untreated samples are quite similar. They weigh 2,044 and 2118 kg/m3. These values fall inside the British standard code's specified range (BS EN 12390-7, 2019).

Table 2: Wet Density of the concrete produced from the two water samples

Sample	Weight (kg)	Volume (m3)	Wet density (kg/m3)
J1	6.9	0.003375	2,044
J2	7.15	0.003375	2,118

Slump

Table 4.2 displays the slump test results for concrete made with treated and untreated water, which are 75 and 90 mm, respectively. They are categorized as real slump in accordance with BS EN 12350-2 (as specified in 2019 updated version).

Table 3: Slump test result of the concrete produced from the two water samples

Test Samples	Slump (mm)
J1	75
J2	90

Compressive Strength Result

Tables 4.3 and 4.4 displayed the compressive strength data of the concrete in the study, following 3, 7, 14, and 28 days of curing period. It was found that concrete made from untreated water has a compressive strength of 42.17 N/mm2, while concrete made from treated water has a compressive strength of 40.96 N/mm2 after 28 days. These numbers significantly exceed the design strength of 25N/mm2.

Table 4: Compressive strength of concrete from untreated water at Different

Description	Weight (kg)	Density (kg/m³)	Avg. Density (kg/m³)	Load (kN)	Compressive Strength (N/mm²)	Avg. Compressive Strength (N/mm²)
	1.45	1450		173.73	17.37	
J1 (3days)	1.7	1700	1616	182.1	18.21	17.74
	1.7	1700		176.46	17.64	
	2.2	2200		282.31	28.23	
7days	2.25	2250	2250	295.91	29.59	28.83
	2.3	2300		286.74	28.67	
	2.4	2400		397.02	39.7	
14days	2.2	2200	2350	369.17	36.91	37.37
	2.45	2450		355.09	35.5	
	2.5	2500		419.08	41.9	
28days	2.3	2300	2383	455.25	45.52	42.17
	2.35	2350		390.89	39.09	

Table 5: Compressive Strength of Concrete from Treated Water at Different Curing Days

Description	Weight (kg)	Density (kg/m³)	Avg. Density (kg/m³)	Load (kN)	Compressive Strength (N/mm²)	Avg. Compressive Strength (N/mm²)
	2.00	2000		178.68	17.87	
J2 (3days)	2.35	2350	2150	173.55	17.36	17.72
	2.1	2100		179.19	17.92	
7days	2.25	2250	2317	290.36	29.04	28.04
	2.5	2500		282.03	28.2	

	2.2	2200		268.79	26.88	
	2.3	2300		347.52	34,75	
14days	2.45	2450	2383	402.04	40.2	36.7
	2.4	2400		351.49	35.15	
	2.5	2500		433.89	43.39	
28days	2.45	2450	2416	402.04	40.2	40.96
	2.3	2300		392.85	39.29	

Comparison of the Compressive Strength Values

Figure 1 compares the compressive strength of concrete made with treated and untreated water. It is evident that the concrete from untreated and treated water has fairly similar compressive strength values at three, seven, and fourteen days. After 28 days, the strength of concrete made from untreated water rose by 3% compared to concrete made from treated water. This has demonstrated that for the manufacturing of concrete, untreated water is preferable to treated water. And this can be attributed to the high iron concentration might be the cause of this.

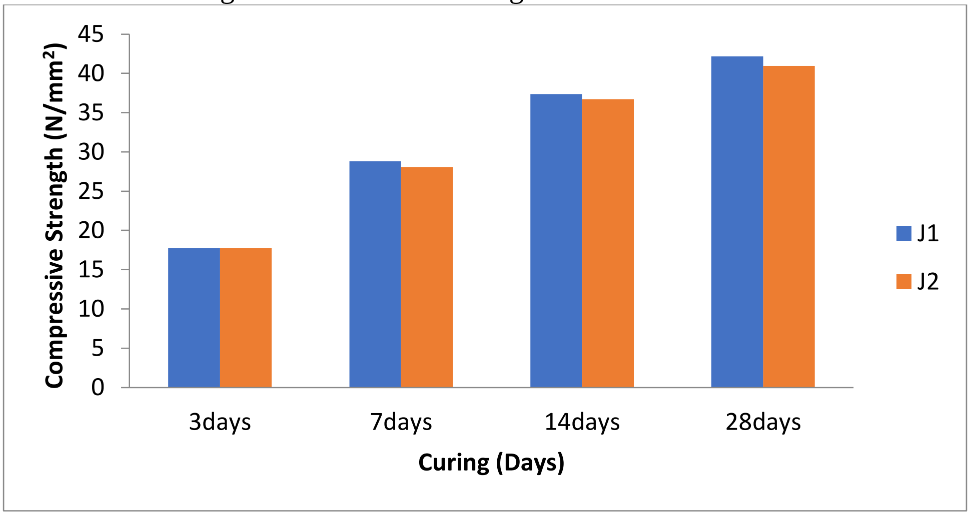

Figure 1: Comparison of the Compressive Strength of Concrete from untreated and treated water

Conclusion

The study concludes that the untreated water used to make concrete is not significantly impacted by oil spills within Amassoma. Instead, it strengthens the concrete. One may argue that the water used to make concrete in Amassoma, Bayelsa state, is impacted by oil pollution but this study has shown that it rather enhances the concrete.

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