# STRENGTH PERFORMANCE OF CONCRETE CURED IN OIL SPILLAGE CONTAMINATED WATER SOURCE IN AKWA IBOM STATE

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**Abstract**
Concrete interacts with substances within its environment. These interactions often have significant effects on the properties of concrete made from ordinary Portland cement. The study assesses the effects of oil spillage contaminated water curing on the performance of concrete. The parameters studied were; water absorption, compressive and flexural strengths at 3, 7, 14, 21 & 28days. The result of the physiochemical analysis of the crude oil contaminated water sourced from the study area indicated an acidic medium with acidity index of 4.77, a Ph value of 5.3, turbidity of 0.6 and it also contained Tetraoxosulphate (vi) acid ($H_2SO_4$) of 0.0116 mg/l and Trioxonitrate (v) acid $HNO_3$ of 0.1905 mg/l. Concrete specimens were prepared to 1: 2: 4 mix using a water to cement ratio of 0.55 and cured in the contaminated water for 3, 7, 14, 21 and 28 days. The results obtained indicated a reduction in the compressive and flexural strengths with 15% and 8% for 3days and 36% and 20% for 28days curing ages respectively, these reductions in strength were attributed to the reaction between Portland cement concrete with sulphates and nitrates compounds present in the contaminated water. Increased water absorption of 4.81% after 3days and 8.97% after 28days was also observed.

**Keywords:** Concrete strength, contaminated water, crude oil, oil spillage, water absorption.

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## INTRODUCTION

Nigeria is among the major crude oil exporting countries in the world. Crude oil is drilled mainly in the Niger delta region. Crude oil is often found mixed with natural gas, which must be separated from the oil during extraction. In Nigeria the associated gas is generally combusted and flared in the open air. The flared gas destroys the natural resources and local livelihoods, alienate people from their land and adversely affect human development conditions (UNDP, 2006). The Energetic Solution Conference (2004) reported that the Niger Delta region has about 123 gas flaring sites. According to Koffi, (2015), incidence of oil spills associated with petroleum activities has been a common occurrence in the oil rich Niger Delta region of Nigeria and it has been an affliction to the host communities since 1956. The UNDP (2006) reported that between the periods of 1976-2001, 3 million barrels of oil were lost in 6,817 oil spill incidences of which over 70% of the spilt oil was not recovered. In 2001 the western operations of the Shell Petroleum Development Company (SPDC) recorded a total of 115 incidences of oil spills in which 5,187.14 barrels of oil were spilled and 734,053 barrels of the spilt oil representing 14.2% were recovered (Kadafa,2012). In January 1998, 40,000 barrels of crude oil was spilled by Mobil in Eket, Akwa Ibom State. About 9 million - 13 million (1.5 million tons) of oil has been spilled in to the Niger Delta ecosystem over the past 50 years, this was estimated in (FME, NCF, WWF UK, CEESP-IUCN, 2006). About 25% of the total oil spilled in the Niger Delta between 1976 and 1990, was in the swamps; 69% off shore environment while 6% was recorded on relatively dry land (Niger Delta Environmental Survey NDES, 1997). Due to the constant oil and gas exploration activities in Akwa Ibom State, its adverse effects on its immediate environment, and the great challenge it pose to the built environment, it is pertinent to identify what effects it has on concrete structures.

When concrete is subjected to a severe environments its durability can significantly decline by degradation (Reddy et al ,2006).The durability aspects of concrete, the chemical attack, which results in volume change, cracking of concrete and the consequent deterioration of concrete, becomes an important part of discussion(Prasad et al,2006). Salts are the primary source of chlorides introduction into concrete (Cretedefender.com). Chloride ions may penetrate into hardened concrete from external sources such as: curing water, de-icing salts, salt spray and sea water (Anwara, and Roushdi, 2013). The Constructor (2017) ascribed the deterioration of concrete structures by seawater to leaching rather than expansion of concrete. The chemical reactions of seawater on concrete are mainly due to the attack by magnesium sulphate and the salt crystallization process of concrete is a major cause for concern (Wegian, 2010). Marine concrete structures that will satiate the long term design requirements must follow a careful procedure in both design and construction stages (Olutoge, and Amusan, 2014).

Curing of concrete plays a major role in developing the microstructure and pore structure of concrete and a good curing practice involves keeping the concrete damp until the concrete is strong enough to do its desired job or withstand its proposed imposed load (Ishmael et al, 2015). Curing has a strong influence on all important properties of hardened concrete such as durability, strength, water tightness, abrasion resistance, volume stability and resistance to freeze/thaw (Kewalramani, 2014). Guneyisi, et al,(2005) reported a compressive strength loss of 10-20% of concrete cubes that were ambient air cured compared to cubes wet cured while Ishmael el al(2015) reported a 29.2% strength gain by concrete cubes cured in water and 28.8% when air cured after 28days.Similarly, Wegian(2010) reported a substantial decrease in compressive strength by 9–14% and 6-28% decrease in flexural strengths after 28 day in mixing and curing in sea water. Olutoge, and Amusan (2014) reported 19.98N/mm$^2$ and 18.75 N/mm$^2$ for concrete cured in fresh water and seawater respectively at 28days which represented 6.2% reduction in compressive strength while Tiwari et al,(2014) obtained a marginal increase in the strength of cubes cast and cured in salt water as compared to those of cast and cured in fresh water at all ages of curing. Asiwaju-Bello et al, (2017) observed an appreciable increase and early strength gain in the salt water concrete cubes to fresh water cubes curing with ceramic powder.

This paper investigates the strength performance of concrete cured in oil spillage contaminated water source.

## MATERIALS AND METHOD

### Materials:

Commercially available Ordinary Portland Cement (Unicem brand) conforming to BS 12 (1996) specification was used. The coarse aggregate (crushed granite) and fine aggregate (natural sand) were used. The water used for mixing was portable drinking water obtained from a borehole conforming to BS EN 1008 (2002) and the crude oil contaminated water used for curing of specimens was obtained from the study area.

Preliminary investigations were conducted on the aggregates in accordance with BS 882(1992) to ascertain their suitability. Various physical tests were conducted on the materials for their characterization and assessment of conformity with other relevant standards.

### Method:

Thirty 150mm x 150mm x 150mm solid concrete cubes and twenty, 750mm x 150mm x 150mm concrete beams were cast to a mix ratio of 1:2:4 proportioned by weight and cured for 3, 7, 14, 21 and 28 days. The water to cement ratio of 0.55 was adopted after series of trial workability slump tests on the fresh mix in accordance with BS EN 12350-2(2009) before it was filled in moulds and compacted in three (3) layers with a 16mm diameter tamping rod. The resulting mix was transferred to the steel solid mould and tamped uniformly with 35 blows per layer in three layers over the cross section of the mould with a tamping rod. The content was de-moulded after 24 hours as a fresh concrete and cured in the curing tanks.

The concrete cubes and beams were cured in a plastic drum by immersion in both portable water with crude oil contaminated water at room temperature throughout the period of testing (3, 7, 14, 21 and 28 days) before being tested for compressive and flexural strength. The compressive and flexural strengths were tested in accordance with BS 1881:116(1990) and BS 1881:118(1990) respectively.

## RESULTS AND DISCUSSION

### Physiochemical Analysis of Crude oil contaminated water

Table 1 indicates that the pH is acidic which is below the World Health Organization (WHO) and Environmental Protection Agency (EPA) standards for portable water. This pH value was also lower than 6.3 obtained by Ukpong & Peter (2012) and 7.8 obtained by Olutoge, and Amusan (2014) for sea water. It also showed an acidic concentration of 4.771 mg/l. It had two predominant acids; $H_2SO_4$ (Tetraoxosulphate (iv) acid) and $HNO_3$ (Trioxonitrate (v) acid, with concentrations of 0.0115 mg/l and 0.1905 mg/l respectively.

**Table 1 Physiochemical Parameters of Crude oil contaminated water**
* World Health Organization (WHO) and Environmental Protection Agency (EPA) standards for portable water.

| PARAMETERS | RESULT | *WHO | *EPA |
|---|---|---|---|
| **pH** | 5.3 | 6.5-8.5 | 6.5-9.5 |
| **Appearance** | Colourless | | |
| **Odour** | | Odourless | |
| **Temperature($^0$C)** | 24 | 35- 40 | |
| **Total Dissolved Solid(TDS)(ppm)** | 11.842 | 500 | |
| **Conductivity** µS | 47.6 | 400 | 2500 |
| **Salinity** | | - | 12 – 38 |
| **Acidity (mg/l)** | 4.771 | - | - |
| **Alkanity (mg/l $CaCO_3$)** | 1.076 | 200mg/l | 400 |
| **Total hardness (mg/l $CaCO_3$)** | 8.014 | - | - |
| **Turbidity (FTU)** | 0.6 | 5 NTU | - |
| **Ca (mg/l $CaCO_3$)** | 0.142 | - | - |
| **Mg(mg/l $CaCO_3$)** | 1.772 | - | - |
| **Sulphate (mg/l)** | 1.184 | 500 | 250 |
| **Chloride (mg/l)** | 0.229 | 250mg/l | 250 |
| **Nitrate (ppm)** | 0.328 | 10mg/l | 50 |
| **Nitrite (ppm)** | 0.338 | | |
| **Dissolved Oxygen(DO) (mg/l)** | 4.189 | - | - |
| **Bio-chemical Oxygen Demand (BOD)(mg/l)** | 0.911 | 50mg/l | ≤ 5 |
| **Chemical Oxygen Demand COD(mg/l)** | 1.137 | 200mg/l | - |
| **Phosphate(mg/l)** | 0.172 | 5mg/l | - |
| **Total suspended solid(TSS)(mg/l)** | 11.842 | 30mg/l | 30mg/l |
| **Total solid (mg/l)** | 4.119 | 1000mg/l | 1000mg/l |
| **Total $H_2SO_4$ (mg/l)** | 0.0116 | | |
| **Total $HNO_3$ (mg/l)** | 0.1905 | | |

**Water Absorption:**
The variation in the water absorption with curing ages presented in figure 1 shows increased water absorption of 4.81% after 3days and 8.97% after 28days. This increase in absorption is attributed to the reaction between Portland cement and $H_2SO_4$ (Tetraoxosulphate (iv) acid) as well as $HNO_3$ (Trioxonitrate (v) acid) present in the contaminated water which build-up internal stresses leading to the breakdown of the structures.

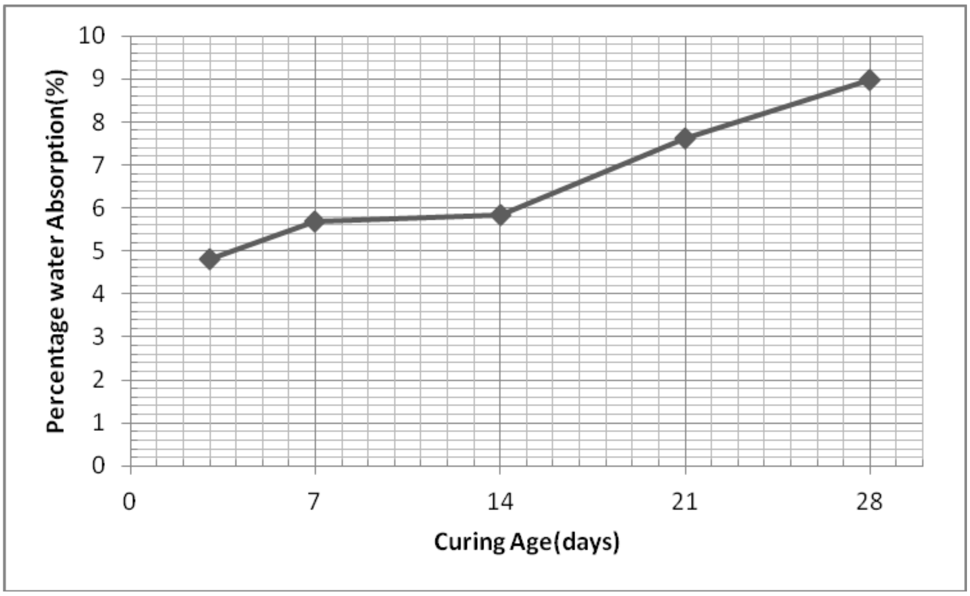


**Figure 1: Variation in percentage water Absorption with curing ages of concrete**

**Compressive and Flexural Strengths:**
The variation in the compressive and flexural strengths of concrete cubes at 3, 7, 14, 21 and 28 days cured in portable water and contaminated water are presented in figure 2 & 3. The concrete cubes early strength development indicated 20% attainment of strength at 3days when cured in the contaminated water as against 37% in portable water curing. At 7days, it was 18% in contaminated water curing, which was less than 65% at 7days in salt water reported by Asiwaju-Bello et al, (2017).The variations in the compressive strength showed a 15% reduction after 3day, 21% reduction after 14days and 36% reduction after 28days which was greater than 9-14%, and 6.2% decrease in compressive strength at 28days reported by Wegian (2010) and Olutoge, & Amusan (2014) respectively. Similarly, 8 %, 11% and 20% reductions in flexural strength were also reported after 3, 14 and 28days respectively, which were within the range of 6-28% decrease in flexural strength at 28days reported by Wegian (2010). These reductions in compressive strength are attributed to the reaction between calcium aluminates and sulphates present in the contaminated water; the product of the reaction becomes calcium sulphur aluminates causing loss of bond between the cement pastes and aggregates hence a gradual disintegration of the concrete strength.

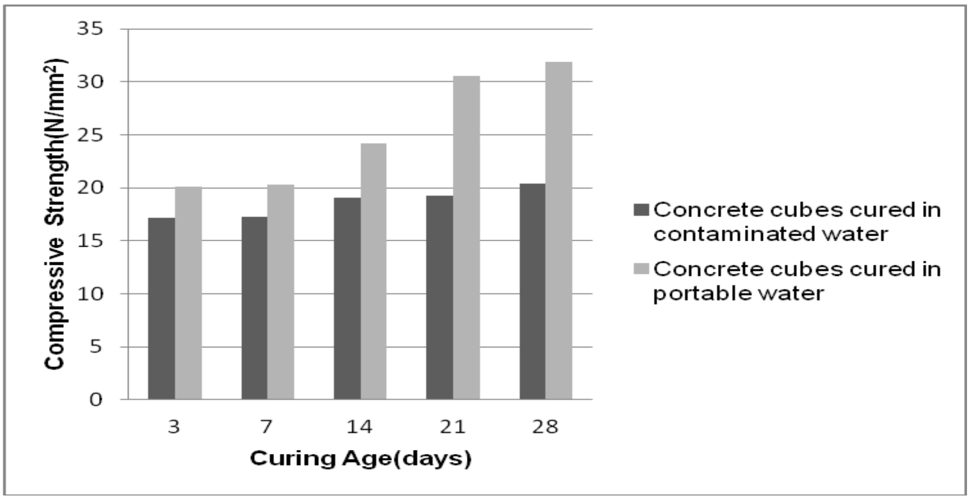


**Figure 2: Variation in the Compressive strength of Concrete with curing ages cured in different water sources.**

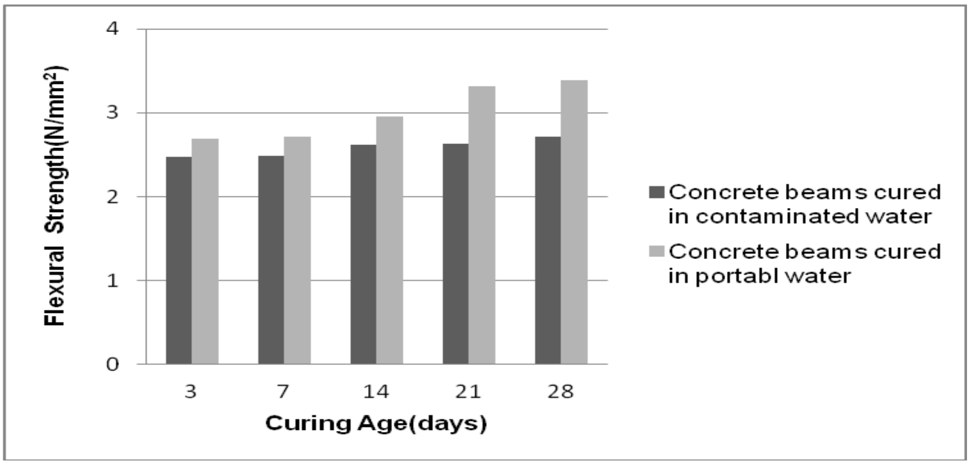


**Figure 3: Variation in the Flexural strength of Concrete with curing ages cured in different water sources.**

**CONCLUSION:** The following conclusions can be deduced.

- The activities of oil and gas explorations have adversely affected concrete structures in the in the study area, especially structures constructed with ordinary Portland cement.
- Water samples obtained from the study area contained $H_2SO_4$ (Tetraoxosulphate (iv) acid) and $HNO_3$ (Trioxonitrate (v) acid, with concentrations of 0.0115 mg/l and 0.1905 mg/l respectively. Acidic index of 4.77 with pH of 5.3 and turbidity index of 0.6 was also reported in the water samples.
- Increased water absorption of 4.81% after 3days and 8.97% after 28days was also noted due porosity condition of the concrete after curing in the contaminated water.
- The compressive and flexural strength reductions of 15% and 8% for 3days and 36% and 20% for 28days curing ages respectively were recorded attributed to the reaction between Portland cement concrete with sulphates and nitrates compounds present in the contaminated water causing loss of bond between the cement pastes and aggregates.
- The use of ordinary Portland cement alone in construction in the study area should be avoided due to its weak resistivity to chemical environmental aggressions hence mineral admixtures are highly recommended.

## REFERENCES

Anwara, M. and Roushdi, M.(2013). Improved concrete properties to resist the saline water using environmental by-product. National Water Research. Water Science. 27.pp 30–38. http://dx.doi.org/10.1016/j.wsj.2013.12.003.

Asiwaju-Bello, I., Olalusi, O,. and Olutoge, F.(2017). Effect of Salt Water on the Compressive Strength of Ceramic Powder Concrete. American Journal of Engineering Research (AJER). Vol.6,(4), pp-158-163. www.ajer.org.

BS 12:1996, Specification for Portland Cements, British Standard Institute.

BS 882:1992, Specification for aggregate from natural resources for concrete, London. Bristish Standard Institution

BS EN 1008 : 2002, Mixing water for concrete, British Standard Institute.

BS 1881: Part 116, (1990). Methods for Determination of Compressive Strength of Concrete Cubes. British Standard Institution,

BS 1881: Part 118, (1990). Methods for Determination of Flexural Strength. British Standard Institution,

BS EN 12350 Part 2:2009, Testing fresh concrete: slump test. London.

Crete Defender (2017). How Salts Damages Concrete. Retrieved from www.cretedefender.com on 26/11/2018

Energetic Solution Conference (2004). In : Kadafa, A. A. (2012) . Environmental impacts of oil exploration and exploitation in the Niger Delta of Nigeria: *Global journal of science frontier research environment & earth sciences.* Vol.12(3).

Federal Ministry of Environment Abuja, Nigerian Conservation Foundation Lagos, WWF UK and CEESP-IUCN Commission on Environmental, Economic, and Social Policy, May 31,(2006). *Niger Delta Resource Damage Assessment and Restoration Project.*

Guneyisi, E., Ozturan T., &Gesoglu, M. (2005). A study on Reinforced Corrosion and Related Properties of Plain and Blended Cement Concrete under Different Curing Conditions. Cement and Concrete Composites, Vol. 27, pp 440-461

Ishmael, O. Samuel, S. Abednego, G and Paul, A (2015). Comparative Analysis of Non-Destructive Strength of Water Cured and Air Cured Concrete. American Journal of Civil Engineering. Vol. 3, No. 6, pp. 194-198. doi: 10.11648/j.ajce.20150305.17

Kadafa, A. A. (2012). Environmental impacts of oil exploration and exploitation in the Niger Delta of Nigeria: *Global journal of science frontier research environment & earth sciences.* Global Journals Inc. (USA).Vol.12(3).

Kewalramani, M.A(2014). Environmentally Sustainable Concrete Curing with Coloured Polythene Sheets. Asia-Pacifi c Chemical, Biological & Environmental Engineering Society (APCBEE) Procedia 9. pp 241 – 246. www.sciencedirect.com.

Koffi, U. S. (2015). Petroleum Activities, Wetland Utilization and Livelihood Changes in Southern Akwa Ibom State, Nigeria. *Lund University GEM Thesis Series.* (10)

Niger Delta Environmental Survey (NDES): Environmental and Socio-economic characteristics. Environmental Resources Managers Ltd. Ikoyi, Lagos. Vol.1. Pg. 249, 1997.

Olutoge, F. A and Amusan, G. M (2014). The Effect of Sea Water on Compressive Strength of Concrete. International Journal of Engineering Science Invention. Vol. 3 (7) Pp.23-31 www.ijesi.org.

Prasad, J. Jain, D. K. and Ahuja, A. K (2006) Factors Influencing the Sulphate Resistance of Cement Concrete and Mortar; Asian Journal of Civil Engineering (Building and Housing). Vol.7,(8) Pp 259 - 268.

Reddy, V.V, Rao, H.S, and Jayaveera, K.N (2006). Influence of strong alkaline substances(sodium carbonate and Sodium bicarbonate) in mixing water on strength and setting properties of concrete. Indian Journal of Engineering and Materials Sciences. Vol.13. pp123-128

The Constructor (2017).Concrete Exposed to Seawater – Effects and Preventions. Sadananda, A.(Eds). https://theconstructor.org/concrete/concrete-seawater-effects-preventions/843/

Tiwari ,P., Chandak, R. and Yadav,R.K (2014). Effect of Salt Water on Compressive Strength of Concrete. International Journal of Engineering Research and Applications. Vol. 4,(4), pp.38-42

Ukpong, E. C. and Peter, B. U. (2012). *Physic-chemical and Bacteriological analyses of Drinking water in Ibeno Local Government Area of Akwa Ibom State.* Nigerian Journal of Technology (NIJOTECH) vol.31, pp. 115-127.

United Nations Development Programme UNDP, (2006). *Niger Delta human development report.* Abuja, Nigeria: pp.185-186.

Wegian, F.M (2010) Effect of seawater for mixing and curing on structural concrete, The IES Journal Part A: Civil & Structural Engineering, 3:4, 235-243, DOI:10.1080/19373260.2010.521048.