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EFFECT OF CRUDE OIL CONTAMINATION ON THE COMPRESSIVE STRENGTH OF CONCRETE

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ABSTRACT
This paper investigates the influence of crude oil contamination on the compressive strength of concrete. Concrete produced in regions where crude oil is exploited can have significant changes in its properties as a result of crude oil contamination of its constituents. Various cubes of concrete with varying degrees of crude oil contamination were processed in the laboratory to determine the effect of contamination on the mechanical properties of concrete. Contamination in concrete was achieved by adding crude oil to the aggregate constituent of the test concrete. It was observed that the presence of crude oil in concrete hinders the bond formation between constituent materials and brings about segregation. Consequently, the presence of crude oil in concrete resulted to variations in workability of the concrete-the higher the percentages of crude oil in the fine aggregate, the higher the workability. Also, lower compressive strengths were observed in contaminated concrete cubes when compared with the controlled cubes. This revealed clearly that crude oil is a compressive strength inhibitor in the production of concrete. The higher the percentages of crude oil in the fine aggregate, the lower the compressive strength obtained. It can be inferred that the optimum crude oil contamination for the achievement of normal compressive strength is as low as 0.3%.

Keywords: *Compressive Strength, Slump Test, Aggregate, Grading Curve, Water-Cement Ratio*

1. INTRODUCTION
Major oil spills heavily contaminate marine shore lines, causing severe localized ecological damage to the near shore community. The harmful effects of oil spill on the environment are many [1]. The growth of the country's oil industry, combined with a population explosion and lack of enforcement of environmental regulations have led to substantial damage to the immediate environment of oil producing areas. The Niger Delta region is a case study here. When there is an oil spill on water, spreading immediately takes place. The gaseous and liquid compounds evaporate. Some get dissolved in water and even oxidize, and yet some undergo bacterial changes and eventually settle to the bottom by gravitational action [1, 2].The soil is then contaminated with a gross effect upon the terrestrial life. As the evaporation of the volatile, lower molecular weight components affect aerial life, so the dissolution of the less volatile components with the resulting emulsified water, affect aquatic life [3].

2. BACKGROUND OF STUDY
Oil spills in the Niger Delta have been a regular occurrence, and the resultant degradation of the surrounding environment has caused significant tension between the people living in the region and multinational oil companies operating there. It is only in the past decade that environmental groups, the federal government, and the foreign oil companies operating in the area commenced steps to mitigate the impacts. Large areas of the mangrove ecosystem have also been destroyed [4].

The Idoho oil spill travelled all the way from Akwa Ibom state to Lagos state, a distance of about 670km, while dispersing oil through the coastal states up to the Lagos coast. This culminated in the presence of a spill of oil on the coastal areas of Cross River state, Akwa Ibom state, Rivers state, Bayelsa state, Delta state, Ondo state and Lagos state [4].

In many villages near oil installations, even when there has been no recent spill, an oily sheen can be seen on the water, which in fresh water areas is usually the same water that the people living there

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drink and use for all their requirements. In April 1997, samples taken from water used for drinking and washing by local villagers were analyzed in the United States of America. A sample from Luawii, in Ogoni, where there had been no oil production for four years, had 18ppm of hydrocarbons in the water, 360 times the level allowed in drinking water in the European Union (E.U.). A sample from Ukpeleide, Ikwerre, contained 34ppm, 680 times the European Union standard [4].

Ukoli [5] observed that for over four decades Nigeria has continued to experience remarkable increases in operational activities in her oil and gas exploration, exploitation, refining and product marketing which is concentrated in Niger Delta region, and that the region has been mired by various degree of health and environmental pollution problems [3]. Regular crude oil spillage on the surface and subsurface water resources, erosion and drainage problems of the built environs culminating in incessant failure of buildings and other onshore structures have become a regular news item [3].

Currently, oil pollution has led to a serious pollution of lands (soils) and water (surface and underground) [6-17]. In some areas, it is difficult to obtain sufficient quantities of uncontaminated fine aggregates. Consequently, occasional use of contaminated fine aggregates occurred. This occurrence makes this research inevitable. This paper investigates nature and properties of concrete produced in these oil producing areas. The compressive strength of crude oil contaminated concrete is compared to that of uncontaminated concrete.

Ayininuola [18] investigated the influence of diesel oil and bitumen on compressive strength of concrete. He used contaminated marine sand – contaminated with both diesel oil and cut-back bitumen-separately in the production of his test concrete. Both uncontaminated and contaminated sands were used to prepare concrete cubes using mix ratio 1:2:4 and water cement ratio of 0.6. He observed that the uncontaminated fine sand, cement hydration continued for a long period of time. According to him the Initial rate of hydration was very fast leading to rapid gaining in concrete compressive strength. But with time, lesser cement particles remained for hydration, hence the reduction in the rate of strength development. The behaviour of compressive strength of concrete cubes cast with diesel oil contaminated sand was quite different from those of the control. In all the three sets of cubes investigated for diesel oil contamination, there were initial rapid increase in compressive strengths development up to the 28 day of concrete casting. Between 28 and 58 day, the rate of strength development continued though the rate of increase declined. Beyond 58 day reduction in concrete cubes compressive strengths was recorded. In addition, the higher the percentages of diesel oil present in the fine aggregate, the lower the resulting concrete strength irrespective of concrete age. Ejeh and Uche [19] in their work on the effect of crude oil spill on compressive strength of concrete materials, subjected concrete specimens to concentrated crude oil solution and simulated water/crude oil mix. The samples were cured in the media with ambient temperature at immersion ages of 3, 7, 28, and 56 days. The results obtained showed that the ordinary Portland cement is susceptible to different aggressiveness of the solutions of crude oil concentrations as they led to low rates of strength development of concrete specimens.

3. MATERIALS AND METHOD

The two samples (fine and coarse aggregates) of 1000g each were soaked in water for 24hrs to remove deleterious materials which were removed by decantation method. After decanting, the samples were dried at room temperature in a thermostatically, controlled oven at 110ºC.

The dry and clean sieves were arranged in series where the size of the smaller sieve is one-half the size of the larger one in the decreasing order of size. The samples were weighed and put into the largest sieve. Shaking of the stacked sieves followed for two minutes with a varied motion, backwards and forward, left to right, circular, clockwise and anti-clockwise and with frequent jarring so that the material is kept moving over the sieve surface in frequently changing direction for hand sieving. Materials retained on each sieve were weighed together with any material cleaned from the mesh. The materials on the pan or receiver were also weighed.

Working from the finest size upwards, the cumulative percentage (to the nearest one percent) passing each sieve was calculated. This percentage was used in plotting the grading curve in a graded chart, where the ordinates represent the cumulative percentage passing and the abscissa are the sieve apertures plotted to a logarithmic scale which gives a constant spacing for the standard series of sieves. Figures 1a and 1b show the grading curves for fine and coarse aggregates.

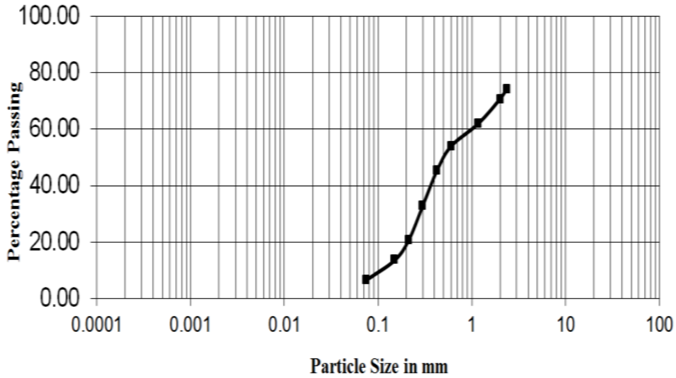

Figure 1a: Grading curve for fine aggregates

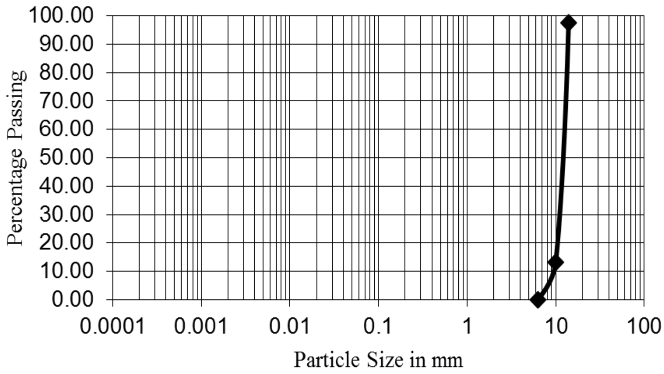

Figure 1b: Grading curve for coarse aggregates

3.1. Batching of the Constituent Materials

In general, concrete is mixed according to the appropriate batch related to work and promptness of the construction. The batching operation was carried out in a standard laboratory: Quality Control Laboratory of Hartland Nigeria Limited, Auchi, Edo State. The weight measurement method was applied in mixing raw materials such as cement, contaminated and uncontaminated fine aggregates, coarse aggregate, portable water and crude oil. This method requires a stringent quality control. Appropriate weighing instrument were used in weighing the constituent materials and this was implemented systematically and accurately to every batch mixed. Concrete can be mixed either by hand or by machine. In this work the later technique was applied. The raw materials were weighed and placed into the machine. The machine was rotated until the materials were completely and homogenously mixed as water is being added. After the mixing, the concrete was formed a standard steel cube formwork at conducting the slump test.

3.2. Slump Test

The slump value was achieved by the use of a slump mould in the form of the frustum of a cone -305mm (12in) high, 203mm (8in) base diameter with a smaller opening of 102mm (4in) diameter at the top. The mould had smooth surface and provided with suitable fort pieces and handles to facilitate lifting. The mould was firmly held against its base and filled with concrete in three layers. Each layer was tampered 25 times with a standard 16mm diameter steel rod. Immediately after filling, the cone was carefully inverted and emptied over a flat plate. The decrease in the height of the center of the slumped concrete is called the slump and this was measured and recorded to the nearest 5mm.

3.3. Concrete Strength Test

One major characteristic of concrete is its high compressibility. The concrete performance test has always been referred to the compressibility i.e. ability of a concrete cube with a dimension of 150 x 150 x 150mm to develop specific compressive strength after 28 days.

There are many techniques known to be applied in order to obtain compressive strength of concrete whether directly or indirectly, destructive or non-destructive test etc. In this work, the method applied was destructive which is the cube compressive test with a dimension of 150 x 150 x 150mm and tested at the ages of 7, 14, 28 and 56 days respectively.

3.4. Compression Test

The main objective of this test is to obtain the compressive strength of the concrete cube specimen. The concrete mix was placed into the mould, which has been smeared with oil for easy removal of the concrete cube. Concrete was compacted in three layers using a 25mm square steel punner with 35 strokes per layer and the surface was leveled using trowel.

After 24 hours, the moulds were opened and the cubes immersed in the curing tank in the laboratory at room temperature. All tests complied with the requirement of BS: 1881, Part 4 [20]. Prior to the test, the cubes/specimens were placed onto the lower steel platen plate with smooth surfaces facing the top and bottom platen plates.

The load weight constantly applied was 12-24N/mm^2/min. until the specimen fails. At failure, the compressive strength which is the resistance expressed in force per unit area of a structural material at failure in a compression test, expressed in

N/mm² was automatically recorded from the compression machine.

4. RESULTS AND DISCUSSION

4.1 Slump Test

Comparing the slump values obtained for each of the contaminated samples with the control sample's value of 45mm as shown in Table 1, the contaminated samples have greater values. This as reasoned can equally lead to segregation. The result of the slump conducted revealed that slump increases with increase in the percentages of crude oil in the fine aggregates. The slump collapsed finally in concrete with 5% crude oil contamination. Since the concrete mix had the same grading of aggregates and under strictly controlled conditions, it then means that crude oil was responsible for the increase in slump and the interference in the cement-water binding reactions thereby delaying or preventing full hydration of cement particles.

Table 1: Slump Test Results

Crude Oil Contamination (%)	Slump (mm)	Degree of Workability
0	45	Low
1	60	Medium
2	80	Medium
3	105	High
4	140	High
5	165	High

4.2. Compressive Strength Test

A total of 72 cubes were cast and cured by flooding. They include concrete mixes 0% crude oil (the control) and with contamination of 1%, 2%, 3%, 4% and 5% of crude oil.

Three cubes were tested daily at the ages of 7, 14 28 and 56 days of the different mixes respectively. However, the surface water, grit and any projecting surface were removed and wiped off before the test was conducted. The crushing test was carried out in accordance with BS 1881-102 (1983). Under this method, the cubes were placed under the crushing machine with the cast faces in contact with the platens of the machine.

4.2.1 0% Crude Oil Contaminated Fine Aggregate (Control Mix)

A good concrete is expected to have its compressive strength increased with age. Similar to those suggested by British Cement Association, BCA [21]. This was actualized by the concrete cube cast with uncontaminated fine aggregate (control mix). The uncontaminated cubes attained 63.5% and 81.4% of their 28 day compressive strength at 7 and 14 days respectively. These observed variations in compressive strengths were similar to those suggested by BCA [21] that for a typical Portland Cement, the approximate relative proportions of the 28 day strength achieved at 7 day and 14 day suggest that it should be 67% and 83% respectively. At 56 days, the compressive strength of the same uncontaminated cube increased but at a slower rate with 107.3% of the 28 day strength. Table 2 shows a summary of the obtained results.

Table 2 Compressive Strength of Concrete (Control Mix)

Testing Days	Compressive Strength (N/mm²)			
	Cube 1	Cube 2	Cube 3	Average
7	14.20	13.80	13.88	13.96
14	17.94	18.04	17.72	17.90
28	21.85	22.14	22.01	22.00
56	23.95	22.50	24.35	23.60

*Slump: 45mm, Quantity of fine aggregate used = 40kg

4.2.2 1% Crude Oil Contaminated Fine Aggregate

At the 7 day of testing, the concrete strength of cubes of 1% crude oil contaminated fine aggregate was 80.5% of the controlled cubes while at the 14, 28 and 56 days of testing, they were 87.4%, 80%, and 78.2% respectively of the controlled cubes. This showed that they were reduced by 19.5%, 12.6%, 19.95% and 21.8% in the 7, 14, 28 and 56 days respectively. Despite the reduction in the compressive strength of the 1% crude oil contaminated fine aggregate that made it not suitable in 1:2:4 concrete mix, it can be used to achieve Grade 15 concrete using the mix ratio of 1:2:4. Table 3 shows a summary of the obtained results.

Table 3 Compressive Strength of Cubes with 1% Crude oil Contamination

Testing Days	Compressive Strength (N/mm²)			
	Cube 1	Cube 2	Cube 3	Average
7	11.12	11.20	11.40	11.24
14	14.98	15.85	16.12	15.65
28	17.28	18.00	17.55	17.61
56	17.83	18.75	18.77	18.45

*Slump: 60mm, Quantity of fine aggregate used = 40kg , Quantity of crude oil used = 1% of the weight of fine aggregate = 400g

4.2.3 2% Crude oil Contaminated Fine Aggregate

The British Cement Association, BCA [21] suggested that for a typical Portland cement, the approximate relative proportions of the 28 day strength achieved at 7 day and 14 day should be 67% and 83% respectively. Also at the 7,14, 28 and 56 days of testing, the compressive strengths of the 2% crude oil contaminated fine aggregate were 70.3%, 76.7%, 71.91% and 68.8% respectively of the controlled cubes. As a result of the reduction in compressive strength, 2% contaminated fine aggregate cannot be used in 1:2:4, but may still be useful in Grade 15 concrete using the same 1:2:4 concrete mix. Other mix proportions may however be used. A suggestion will be 1:1½:3. Table 4 shows a summary of the obtained results.

*Table 4 : Compressive Strength of Cubes with 2% Crude Oil Contamination**

Testing Days	Compressive Strength (N/mm^2)			
	Cube 1	Cube 2	Cube 3	Average
7	9.88	10.02	9.56	9.82
14	13.36	13.91	13.89	13.72
28	15.62	15.96	15.88	15.82
56	15.96	16.38	16.38	16.24

*Slump: 80mm, Quantity of fine aggregate used = 40kg, Quantity of crude oil used = 2% of the weight of fine aggregate = 800g

4.2.4 3% Crude Oil Contaminated Fine Aggregate

The 3% crude oil contaminated fine aggregate had 38% and 51.1% of their 28 day compressive strengths at 7 and 14 days respectively against the 67% and 83% suggested by the British Cement Association, BCA [21]. At the 7, 14, 28 and 56 days of testing, the compressive strengths of the 3% crude oil contaminated fine aggregate were 59.9%, 62.8%, 55.1% and 57.8% respectively of the control cubes. As a result of these reductions, 3% crude oil contaminated fine aggregate should not be used for grades that are not exceeding $10N/mm^2$ but useful in concrete grades that are lesser than $10N/mm^2$ using concrete mix ratio of 1:2:4 and water-cement ratio of 0.5. Table 5 shows a summary of the results obtained.

4.2.5 4% Crude oil Contaminated Fine Aggregate

The 4% crude oil contaminated fine aggregate attained 33.8% and 40.3% of their 28 day compressive strengths at 7 and 14 days respectively against the 67% and 83% suggested by BCA [21]. The compressive strengths at 7, 14, 28 and 56 days of testing were 53.3%, 49.5%, 46.6% and 49.0% respectively of the controlled cubes. As stated earlier in the 3% crude oil contaminated fine aggregate, 4% contamination should not be used at all for concrete grades greater than $10N/mm^2$ using concrete mix of 1:2:4 but can be used for grades not exceeding $10N/mm^2$ using the same concrete mix of 1:2:4. Table 6 shows a summary of the results obtained.

*Table 5: Compressive Strength of Cubes with 3% Crude Oil Contamination**

Testing Days	Compressive Strength (N/mm^2)			
	Cube 1	Cube 2	Cube 3	Average
7	8.26	8.40	8.42	8.36
14	11.20	11.35	11.17	11.24
28	12.24	12.04	12.08	12.12
56	13.61	13.61	13.67	13.63

*Slump: 105mm, Quantity of fine aggregate used = 40kg, Quantity of crude oil used = 3% of the weight of fine aggregate = 1200g

*Table 6: Compressive Strength of Cubes with 4% Crude Oil Contamination**

Testing Days	Compressive Strength (N/mm^2)			
	Cube 1	Cube 2	Cube 3	Average
7	7.75	7.51	7.06	7.44
14	8.45	8.87	9.26	8.86
28	10.13	10.34	10.25	10.24
56	11.47	11.59	11.62	11.56

*Slump: 140mm, Quantity of fine aggregate used = 40kg, Quantity of crude oil used = 4% of the weight of fine aggregate = 1600g

4.2.6 5% Crude Oil Contaminated Fine Aggregate

Here the slump collapsed. The surface areas of fine aggregate particles were coated with crude oil which hindered the physical bond formation between cement paste and fine aggregate. At the 7, 14, 28 and 56 days of testing the cubes, the compressive strengths of the 5% crude oil contaminated fine aggregate were 48.9%, 39.2%, 36.45% and 44.3% respectively of the controlled cubes. Also, the 5% crude oil fine aggregate attained 31% and 31.9% of their 28 day compressive strengths at 7 and 14 days respectively against the 67% and 83% suggested by the British Cement Association, BCA [21]. The compressive strengths of cubes with 5% crude oil contaminated fine aggregate were very low when compared with the control cubes and therefore must be used for 1:2:4: concrete mixes unless when it is to be used for blinding purposes in foundations.

The summary of the results of cubes compressive strengths is shown in Table 7. Generally, the gain in concrete strength is most marked at early ages and after 28 days the relative rate of gain in strength is much reduced. This is as a result of the presence of tricalcium silicate (C_3S) in the cement. The rate of hydration of cement was very fast in the uncontaminated concrete leading to rapid gain in compressive strength. But with time, lesser cement particles remained for hydration, hence the reduction in the rate of strength development occurred at the 56 day.

The surface area of fine aggregate particles were coated with crude oil which hindered the physical bond formation between cement paste and fine aggregates. The higher the quantity of crude oil present, the higher the barrier to the formation of physical bond responsible for concrete strength would be. The presence of crude oil in the fine aggregate was responsible for the lower rate of strength development. The quantity of cement particles available for hydration process was much at the first few days of concrete casting as expected for a normal concrete; even though the expected bond generated with aggregate was hindered by the presence of crude oil; nevertheless increase in strength development rate still occurred though at an unacceptable rate. Table 8 shows a summary of concrete strengths corresponding to different levels of crude oil contamination.

*Table 7: Compressive Strength of Cubes with 5% Crude Oil Contamination**

Testing Days	Compressive Strength (N/mm²)			
	Cube 1	Cube 2	Cube 3	Average
7	6.21	5.94	8.31	6.82
14	6.85	7.04	7.17	7.02
28	7.20	9.40	7.40	8.00
56	9.99	10.88	10.51	10.46

*Slump: 165mm (Collapsed), Quantity of fine aggregate used = 40kg, Quantity of crude oil used = 5% of the weight of fine aggregate = 2000g

Table 8: Mean Compressive Strengths of Concrete with or without Crude Oil Contamination (N/mm²)

Testing Days	Control Cubes	Crude Oil Contaminated Fine Aggregate				
		1%	2%	3%	4%	5%
7	13.96	11.24	9.82	8.36	7.44	6.82
14	17.90	15.65	13.72	11.24	8.86	7.02
28	22.00	17.61	15.82	12.12	10.24	8.00
56	23.60	18.45	16.24	13.63	11.56	10.46

6. CONCLUSION AND RECOMMENDATIONS

The influence of crude oil contamination on the compressive strength of concrete was investigated and the following conclusions drawn:

(a) The presence of crude oil in concrete making hinders the bond formation between constituent materials and brings about segregation.
(b) The presence of crude oil in concrete results in variations in workability. The higher the percentages of crude oil in the fine aggregate, the higher the workability.
(c) Lower compressive strength were observed in contaminated concrete cube when compared to the controlled cubes. This revealed clearly that crude oil is a compressive strength inhibitor in the production of concrete.
(d) The higher the percentages of crude oil in the fine aggregate, the lower the compressive strength obtained.

Finally, it was observed that a little quantity of crude oil such as 1% brought about a 19.95% reduction in the 28 day compressive strength of the 1: 2: 4 concrete mix produced. Thus this suggests that crude oil in small proportion in concrete making materials should be properly evaluated and should not be used for 1:2: 4 mix if equal or greater than 1%. Instead, the 1% and 2% contaminated fine aggregate should be used for Grade 15 concrete while the 3% contaminated fine aggregate should also be used for Grade 10 concrete using the same mix ratio of 1: 2: 4 and water – cement ratio of 0.5.

7. REFERENCES

[1] Benka-Coker, M.O. and Ekundayo, J.A. 'Effects of an Oil Spill on Soil Physico-Chemical Properties of a Spill Site in the Niger Delta Area of Nigeria', *Journal of Environmental Monitoring and Assessment*, Volume 36, Number 2, pp.93-104, 1994.

[2] Atlas, R. M. 'Petroleum Biodegradation and Oil spill Bioremediation'. *Marine Pollution Bulletin* 31, pp.178-182, 1995.

[3] Akpofure, E.A., Efere, M.L. and Ayawei, P. '*The Adverse Effects of Crude Oil Spill in the Niger Delta'* Urhobo Historical Society, 2000.

[4] Nwilo P. C and Badejo O. T. 'Impacts and Management of Oil Spill Pollution', *International Oil Spill Conference*, Miami, Florida, 2005.

[5] Ukoli, M. K. 'Environmental Factors in the Management of the Oil and Gas Industry in Nigeria', Available on http://www.warmofloor.co.uk/pages/environmenta lpdf [Accessed on 2/12/2005].

[6] Alexandra Gas and Oil Connections, 'Forms Oil Spill Detection Agency', Available on

http://www.gasandoil.com/goc/news/nta40213.htm [Accessed on 3/16/2006].

[7] Calabrese, E.J., Kostecki, P.T and Bonazountas, M. *Hydrocarbon Contaminated Soils*', CRC Press, Taylor and Francis Group, Taiwan, Vol II, 1991.

[8] Hoff, R. 'Bioremediation: An Overview of its Development and Uses for Oil Spill Cleanup', *Mar. POLLUT. Bull.* 26, 476-481, 1993.

[9] Onabolu, O. A. '*Effect of Hot Crude Oil on Concrete for Offshore Storage Application*', PhD Thesis, University of London, pp. 298, 1989.

[10] Parthiphan, K. 'Oil Spill Sensitivity Mapping Using a Geographical Information System', Department of Geography, University of Aberdeen. EGIS Foundation, 1994.

[11] Vazirani, V. N. and Chandola, S. P. *'Concise Handbook of Civil Engineering',* S Chand and Company Ltd, Ram Nagar, New Delhi-110055, 2008.

[12]. Wardley-Smith, J. '*The Control of Oil Pollution on the Sea and Inland Waters*', Graham and Trotman Ltd. United Kingdom, 1976.

[13] Teychenné, D.C., Franklin, R.E., and Erntroy H.C. *'Design of Normal Concrete Mixes',* Building Research Establishment, Transport and Road Research Laboratory, Department of Environment, 1978.

[14] Neville, A. M. and Brooks, J. J. *'Concrete Technology',* First Edition ELBS Publishers, 1994.

[15] Prince, R. 'Petroleum Spill Bioremediation in Marine Environments', *Critical Rev. Microbial,* 19(4), 217-242, 1993.

[16] Wilson, S. A., Langdon, N. J. and Walden, P. J. 'The Effects of Hydrocarbon Contamination on Concrete Strength', *Proceedings Institution of Civil Engineers Geotechnical Engineering,* Thomas Telfords, London, pp.189-193, 2001.

[17] Sandberg, E.C. *'Development of Remote Sensing for Coast Guard Applications',* Remote Sensing', No. 28 pp. 12, 1996.

[18] Ayininuola, G.M. 'Influence of Diesel Oil and Bitumen on Compressive Strength of Concrete', *Journal of Civil Engineering (IEB),* Vol.37 (1) pp.65-71, 2009.

[19] Ejeh, S.P. and Uche, O.A.U. 'Effect of Crude Oil Spill on Compressive Strength of Concrete Materials', *Journal of Applied Sciences Research,* 5(10): pp.1756-1761, 2009.

[20] British Standard Institution, BS: 1881- 102, Method for determination of compressive Strength of Concrete cubes, 1983.

[21] British Cement Association. Specifying Concrete to BS EN 206-1/BS 5500, 2001