EFFECT OF HYDROCARBON IMPURITIES ON THE COMPRESSIVE STRENGTH OF CONCRETE

By

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Abstract.

While in its fresh and hardened state, concrete often interact with its environment which can adversely affect its engineering properties. This paper reports the results of investigation into the effect of hydrocarbon (diesel) impurities on the compressive strength of concrete made with ordinary Portland cement (OPC). The mixing waters for the normal concrete were contaminated in the order of 5,10,15,20 and 25% respectively with hydrocarbon (diesel) impurities to prepare concrete cubes using mix ratio 1:3:6 and water-cement ratio of 0.5. The results revealed that the higher the percentage of diesel oil in mixing water, the lower the concrete compressive strength obtained. The 28-day compressive strengths diesel oil contaminated concrete cubes were in the range of 86.89% to 47.23% of the control concrete cubes. The use of hydrocarbon contaminated water in concreting should be avoided as much as possible.

Keywords: *Compressive Strength, Concrete, hydrocarbon, impurities.*

1.0 INTRODUCTION

Concrete is a mixture of cement, water, fine aggregate (sand, quarry dust) and coarse aggregate (gravel, granite, crushed stone) which hardens to a stone-like mass (Scott, 1991).

Concrete strength is often regarded as the most important property of concrete. The compressive strength of concrete is about ten times its tensile strength (British Cement Association, 2001). Concrete suffers from one major drawback compared with other material like steel and timber, its strength cannot be measured prior to its being placed. Factors affecting concrete compressive strength are water-cement ratio, mix ratio, degree of compaction, type of cement, the grades of aggregates, design constituently, mixing method, placement, curing method and presence of contaminants. Contaminants in concrete may be salts (Chlorides, sulphates, etc), silt, clay and hydrocarbon (petroleum product) etc. Generally, raw materials for concrete production should be free from contaminants.

According to Gambahir, (2004), the strength and durability of concrete is reduced due to the presence of impurities in the mixing water. The quality of water is important because the impurities in it will interfere with the setting of the cement, which may adversely affect the strength of the concrete or causing the staining of the concrete surface leading to the corrosion of the reinforcement. For this reason, suitability of water for mixing and curing purposes should be considered. Generally water satisfactory for mixing is also suitable for curing.

In organic chemistry, a hydrocarbon is an organic compound consisting entirely of hydrogen and carbon. The hydrocarbon to be considered is diesel and its presence in water makes the water impure. One of the glaring physical properties of such water is the silver colouration noticed on the surface of the water because hydrocarbons do not mix with water.

Observation made has shown that diesel is a very common hydrocarbon on site that can easily contaminate water due to the negligence of the construction workers through different processes or operations. Some of the processes include the ones listed below:

- When there is scarcity of water tanker, diesel tankers are used as substitute for water supply and storage because of their same tank sizes.
- Pumping devices used for diesel pumping sometimes are used for pumping of water to construction site.
- Concrete mixer uses diesel as source of power and any leakage in its system would promote or aid a mix up between diesel and the concrete when mixing.
- Tanks and drums used for storage of water are sometimes used for storing diesel on site.

- Another area by which hydrocarbon contamination can take place is through oil spillage. This is a major environmental concern in the Niger Delta area of Nigeria. Other areas are not left out as oil spillages occur are a result of pipeline vandalism and inadequate care on oil production operations. Between 1976 and 1996, Nigeria recorded a total of 4,835 oil spillage incidents that resulted in a loss of about 1.9 billion barrels of oil to the environment (Badejo and Nwilo, 2004). Currently, oil pollution has led to serious pollution of lands (soils) and water (surface and underground). In some areas, it is difficult to obtain sufficient quantities of uncontaminated fine aggregates. Consequently, occasional use of contaminated fine aggregates occurred. This study focuses on the effect of hydrocarbon impurities on the compressive strength of concrete.

2.0 EXPERIMENTAL WORK

To perform the objectives of this study, crushed granite aggregate concrete was mixed according to ASTMC 192-90a. The specifications of the specimens, concrete proportions and testing conditions are as follows:

Cube specimens with dimensions 15omm x 150mm x 150mm

Cement: Ordinary Portland cement 292kg/m^3

Fine aggregate: Local sand (621kg/m^3)

Coarse aggregate: crushed granite (1400kg/m^3)

Water : 146 litres (w/c = 0.50)

Percentage of contaminant (diesel) added:

0, 5, 10, 15, 20 and 25%

Curing age: 28 days

The fresh concrete mixes were produced with varying degrees of hydrocarbon contaminants (i.e. 0%, 5%, 10%, 15%, 20% and 25% of diesel present in the water as contaminant) using manual method of mixing. Immediately after mixing, the fresh concrete mixes were tested for slumps and compacting factors respectively. The slumps were determined according to ASTMC 143-90a while the compacting factors were determined according to BS 1881: part 103: 1993. After this, eight cubes were cast for each of the mixes given a total forty-eight cubes in all. The cubes were left in the moulds for twenty-four hours at room temperature after which they were demoulded and cured in the water-tank for 28 days after which they were crushed to determine their compressive strength.

3.0 RESULTS AND DISCUSSION

The measured values of the compressive strengths for the various concrete mixes used in the study at the room temperature are as shown in table 1a.

The mean compressive strengths and the standard deviations for each concrete mix used in the study were determined from equations 1 and 2 and are as shown in table 1b.

Mean cube strength,

$$\bar{x} = \sum_{i=1}^{n} \frac{x}{n} \quad \text{………………….. Equation 1}$$

Where:-

x = the value of the different items in the distribution

n = the total number of items in the distribution

i = 1, 2, 3, ………………….

Table 1a: compressive strength of cubes cast with clean and contaminated mixing water at 28 day's period of curing.

Control Cubes	Hydrocarbon contaminated mixing water				
	5%	10%	15%	20%	25%
24.40	23.69	22.09	16.58	16.13	12.13
26.22	14.56	17.91	13.29	13.33	11.33
22.58	16.04	18.93	17.69	13.42	12.44
20.27	22.40	20.27	15.56	12.98	11.64
24.62	24.62	15.11	18.00	17.78	9.33
21.82	22.13	18.00	16.09	15.56	7.51
25.96	16.36	16.06	13.33	13.73	12.98
25.11	25.64	17.96	15.64	16.67	12.53

All values are in N/mm^2

3.1 Measuring Dispersion

The standard deviation of each group was determined using equation 2 given below.

$$\text{Standard deviation, } \sigma = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n}} \quad \text{Eq.2}$$

For the whole experiment, the results of the standard deviations are as shown in table 1b.

Table 1b: Mean and standard deviation for 28days curing.

Percentage impurity added (%)	**Mean Comp. strength $(\overline{x})$ (N/mm^2)**	**Standard deviation (N/mm^2)**
Control	23.80	2.08
5	20.68	4.06
10	18.29	2.02
15	15.77	1.64
20	14.95	1.70
25	11.24	1.76

3.2 Regression Analysis

To draw the line of best-fit, regression analysis will be employed. This is done using equations 3 and 4 given below.

$$\Sigma y = an + b\Sigma x \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots equation 3$$

$$\Sigma xy = a\Sigma x + b\Sigma x^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots equation 4$$

Where;

X - represents diesel –water/cement ratio

y - represents mean cube strength

n - is the number of pair of figures

Table 1c: Regression Analysis

X	Y	XY	X^2
0	23.80	0.0000	0.0000
0.05	20.68	1.0340	0.0025
0.10	18.29	1.8290	0.0100
0.15	15.77	2.3655	0.0225
0.20	14.95	2.9900	0.0400
0.25	11.24	2.8100	0.0625
Σx = 0.75	Σy = 104. 73	Σxy = 11.0285	Σx^2 = 0.1375

Substituting the above values in equations 3 and 4, we have:

$$104.73 = 6a + 0.75b \ldots\ldots\ldots\ldots\ldots equation 3.1$$

$$11.0285 = 0.75a + 0.1375b \ldots equation 4.1$$

Equation 3.1 – equation 4.1x8

104.73 = 6a + 0.75b

\- 88.20 = 6a + 1.10b

16.53 = - 0.35b

$$b = \frac{16.53}{0.35} = -47.2286$$

Substitute the value of b in equation 3.1

104.73=6a+0.75(47.2286)

6a=104.73+0.75(47.2286)

6a=104.73+35.4215

6a=140-1515

a = 140.1515/16

a = 23.3585

a = 23.36 (intercept on the y axis which is very close to 23.80)

Intercept on the x – axis

$$= \frac{23.36}{47.2286} = 0.4946 \approx 0.5$$

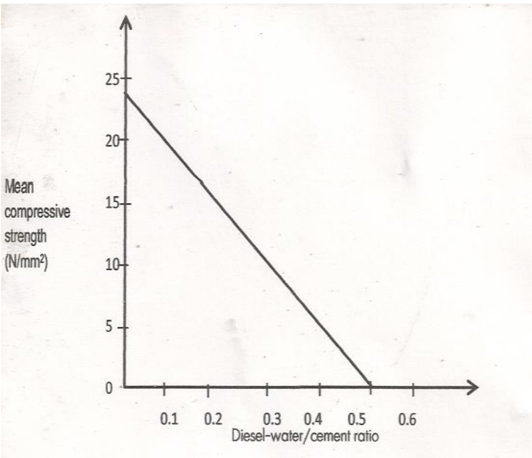

Fig. 1: Line of best fit for mean cube strength versus diesel-water/cement ratio

3.0.3 Pearson Product Moment Coefficient of Correlation.

This is used to show the closeness of relationship between two variables. The formula for finding this is given in Equation 5 below.

$$Y = \frac{\sum \chi y - n\overline{xy}}{n\sigma x - \sigma y} \quad \text{………. equation 5}$$

Where $\bar{x}$ is the mean of variable x

$\bar{y}$ is the mean of variable y

σx is the standard deviation of variable x

σy is the standard deviation of variable y.

Table 1d: coefficient of analysis (1)

Diesel- water cement ratio (X)	**Mean cube strength (Y)**	**(XY)**
0.00	23.80	0.00
0.05	20.68	1.034
0.10	18.29	1.829
0.15	15.77	2.3655
0.20	14.95	2.99
0.25	11.24	2.81
Σx = 0.75	Σy = 104.73	Σxy = 11.0285

$$\bar{y} = 104.73/6 = 17.455$$

$$\bar{x} = 0.75/6 = 0.125$$

Table 1e: coefficient of correlation analysis (ii)

X	**(x-$\bar{x}$)**	**(x-$\bar{x}$)^2**	**y**	**(y-$\bar{y}$)**	**(y-$\bar{y}$)^2**
0	-0.25	0.0156	23.80	6.3400	40.1956
0.05	-0.075	0.0056	20.68	3.2200	10.3684
0.10	-0.025	0.0063	18.29	0.8300	0.6889
0.15	0.025	0.0063	15.77	-1.6900	2.8561
0.20	0.075	0.0056	14.95	-2.5100	6.3000
0.25	0.125	0.0156	11.25	-6.2100	38.5641
Σ = 0.75	Σ = (x-$\bar{x}$) = 0	Σ (x-$\bar{x}$)^2 = 0.055	Σy = 104.74	Σy = 0	Σ (y-$\bar{y}$)^2 = 98.9732

$$\sigma x = \sqrt{\frac{0.055}{6}} = 0.0957,$$

$$\sigma y = \sqrt{\frac{98.9732}{6}} = 4.0614$$

$$r = \frac{11.0285 - 6(0.125)(17.46)}{6 \times (0.0957)(4.0614)}$$

$$= \frac{11.0285 - 13.095}{2.3321} = - \frac{2.0665}{2.3321}$$

$= -0.8861 \quad \approx -0.89$

$r \approx -0.89$ (a strong negative correlation between diesel-water/cement ratio and the mean cube strength)

Aside the negative correlation of -0.89 obtained, the compressive strengths of 5%, 10%, 15%, 20%and 25% diesel contaminants are 86.89%, 76.85%, 66.26%, 62.82% and47.23% of the control experiment respectively indicating that there is a reduction in the compressive strength of the concrete at the end 28 days compressive strength (see fig.2 below.)

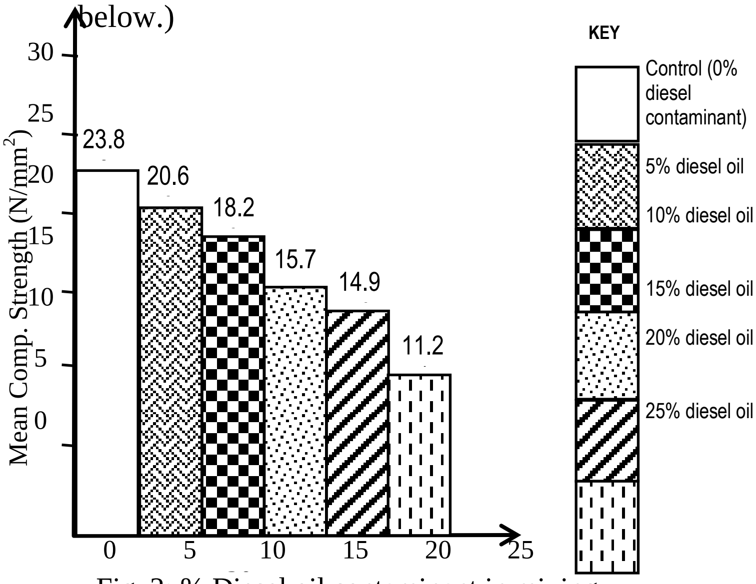

Fig. 2: % Diesel oil contaminant in mixing water.

In the control experiment there was absence of contaminant that could have resulted in the formation of barrier and the reduction of the surface areas of aggregates needed for physical bond formation responsible for strength development, hence the higher value of the compressive strength recorded. In the rest mixes containing 5%, 10%,15%, 20% and 25% diesel oil contaminants, the surface areas of particles for aggregates needed for physical bond formation responsible for strength development were greatly reduced leading to development of lower compressive strengths when compared with that of control. The higher the quantity of the contaminant, the higher the barrier to the formation of the physical bond responsible for concrete strength would be. The results of 20.68N/mm^2, 18.29N/mm^2, 15.77N/mm^2, 14.95N/mm^2 and 11.24N/mm^2 for 5%, 10%, 15%, 20% and 25% contaminants respectively confirmed this assertion. It was observed that as the percentage of the contaminant (hydrocarbon) increases, there is a corresponding decrease in the compressive strength of the concrete cubes.

4.0 CONCLUSIONS

From the study carried out, the following conclusions were arrived at:

1. The presence of diesel impurity of any proportion in the mixing water resulted in concrete of lesser compressive strengths. This shows that diesel oil contaminant in the mixing water is compressive strength inhibitor in concrete production.
2. The 28 days compressive strengths made of contaminated waters of 5% to 25% hydrocarbon impurities were in the range of 86.89% to 47.23% of the control experiment indicating that as the level of contaminant increases there is corresponding reduction in the compressive strength. The observations were similar to those obtained by Ayininuola (2008).
3. A little quantity of hydrocarbon impurity as low as 5% in the mixing water causes a reduction of about 13.11%.
4. A negative correlation of r, equals -0.89 shows that there is a perfect negative correlation between diesel-water/cement ratio and the mean cube strength. That is, as the percentage of diesel in water increases, the cube compressive strength decreases.

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