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Influence of diesel oil and bitumen on compressive strength of concrete

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Abstract

The costal areas of Nigeria are polluted with oil due to oil spillage and pipeline vandalism. The soils in these areas are contaminated to a certain extent. Consequently, the present study focused on the impact of diesel oil and bitumen on compressive strength of concrete. Marine sands were contaminated in the order of 2, 5 and 10% of both diesel oil and cut-back bitumen separately. Both uncontaminated and contaminated sands were used to prepare concrete cubes using mix ratio 1:2:4 and water cement ratio 0.6. The results revealed that both the diesel oil and bitumen contaminated cubes have their compressive strengths increased up to 58 day and 88 day respectively, and reduced thereafter. The higher the percentages of diesel oil and bitumen in sand the lower the concrete compressive strength obtained. The 28-day compressive strengths of diesel oil and bitumen contaminated concrete cubes were in the range of 96.8 to 77.4% and 76.2 to 26.2% respectively of those of uncontaminated concrete cubes. The use of oil contaminated sand in concreting should be avoided as much as possible.

Keywords: Concrete, cement, compressive strength, diesel oil, cut-back bitumen, contaminated sand.

1. Introduction

Concrete is a mixture of cement, water, fine aggregates (sand, quarry dust) and coarse aggregates (gravel, granite, crushed stone), which hardens to a stone-like mass (Scott, 1991). Concrete is used more than any man made materials on earth. As of 2005 about six billion cubic meters of concrete are made each year. Also, concrete powers a US $35 billion industry which employs over two million workers in the United State of America. The People Republic of China currently consumes about 40% of World cement production (Wikipedia, 2006).

The 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 draw back compared with other materials like steel and timber; its strength can not be measured prior to it being placed. Factors affecting concrete compressive strength are water cement ratio, mix ratio, degree of compaction, type of cement, the grades of aggregates, design constituents, 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. Laboratory test of concrete cubes cured in various hydrocarbon compounds was undertaken. The results indicated that petroleum hydrocarbons have no appreciative effect on concrete that has achieved its design strength but creosoete affects hardened concrete that has achieved its design strength (Wilson et al, 2001). The bearing capacity of reinforced concrete sections subjected to oil influence was found to decrease when compared with those of non-oiling influence (Blaszczynski and Scigallo, 2006). The effects of oil-based pollutants on the strength and integrity of building materials were examined. The physical testing programme indicated a positive effect with regard to compressive strength and slump of contaminated aggregate (Al-Mutairi, 1995). Furthermore, the effect of petroleum contamination on concrete strength was conducted. The compressive and flexural strength results indicated that irrespective of the soil type, concrete with higher petroleum contaminated soil (PCS) / sand replacement ratio develops lower values at early and late stages. The presence of contaminants seems to interfere the cement-water binding reactions, delaying or preventing full hydration of cement particles (Calabrese et al, 1991).

Presence of clay (contaminant) in a significant proportion in concrete reduces its compressive strength and increases its shrinkage value (Munoz et al, 2005). Incorporating marine clay and industrial sludge in concrete produced compressive strengths which are fairly comparable to concrete cast with regular aggregates (Tay et al, 2002). Sugar has a strong retarding effect on the setting and hardening of concrete. In severe cases of contamination, the resulting concrete may not set or fail to gain appreciable strength (Cement and Concrete Association of New Zealand, 2005). Seawater in concrete accelerates the early strength of concrete, but reduces its compressive strength by about 10 to 15% (Shetty, 1988).

One of the problems that are characterising communities in Nigeria is oil spillage. In fact, it is a major environmental concern in the Niger Delta area. Other areas are not left out as oil spillage occur as a result of pipeline vandalism and inadequate care on oil production operations. Between 1976 and 1996, Nigeria recorded a total of 4,835 oil spill incidents that resulted in a loss of about 1.9 billion barrels of oil to the environment (Badejo & Nwilo, 2004). Currently, oil pollution has led to a 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 influence of diesel oil and cut-back bitumen on the compressive strength of concrete. Diesel oil and cut-back bitumen are medium and heavy duty products of petroleum respectively.

2. Materials and methods

Enough quantity of fine aggregates (marine sand) and coarse aggregates (granite with sizes not greater than 20mm) were stockpiled. Diesel oil and cut-back bitumen were procured. Each was stored in well labelled container. The cut-back bitumen was made of 60% bitumen and 40% kerosene (as revealed in Manufacturer's specification). Potable water for concreting was obtained at the University of Ibadan Water Treatment Plant. Enough bags of ordinary Portland cement were purchased.

The stockpiled marine sand was air-dried and divided into three parts. One part was for casting controlled concrete cubes; the second was used for diesel oil contaminated cubes production and the last part was reserved for bituminous concrete cubes production. The Batching of concrete constituents in all cases was by weight. The mix ratio adopted was 1:2:4 with water cement ratio of about 0.6. On a flat concrete slab, the right quantity of weighed uncontaminated marine sand was spread and mixed with cement of known weight. Granite of determined weight was added to the sand cement mixture. Already determined weight of potable water was added. The mixture was mixed together to produce a homogeneous fresh concrete.

Steel moulds of size 150mm by 150mm by 150mm with inside coated with oil were placed on flat concrete floor. Fresh concrete was poured into the waiting moulds in three equal instalments or layers. Using a tamping rod, each layer was tamped 35 times to remove entrapped air. After compaction, the top surface of concrete was trowel smooth and levelled with the top of the mould. After hardening sufficiently, each cube was labelled for identification purpose. Altogether, 32 control cubes were prepared and kept in cool environment. After 24 hours, the cubes were removed from moulds and completely immersed in a trough full of potable water.

The second portion of marine sand set aside for diesel oil contaminated concrete cubes production was divided into three parts. One part received 2% of diesel oil, the second received 5% and the third 10%. The measurements were carried out by weighing using 0.1g sensitive balance. The oil and sand were mixed thoroughly and air-dried between 3 to 5 days for maturation. Measured quantity of diesel oil contaminated sand was used to produce concrete cube of 32 in number. The above procedure was repeated for the production of cut-back bitumen contaminated cubes. Prior to mixing, the cut-back bitumen was heated to about 100^{o}C to aid its mixing with marine sand. Altogether, 96 concrete cubes were produced and cured in trough filled completely with potable water. The concrete cubes crushing strengths were determined experimentally on the 7, 14, 21, 28, 58, 88, 118 and 148 day of concrete cubes production. On each day, twelve cubes were crushed made up of four uncontaminated cubes and eight contaminated ones. Each cube was place with the cast faces in contact with the platens of the Universal Testing Machine. The cubes were loaded to failure in accordance with BS 1881: Part 116 (1983).

3. Results and discussions

The summary of the results of cubes compressive strengths is shown in Table 1. Pictorial representations of the results are displayed in Figs. 1 and 2. A sound concrete is expected to have its compressive strength increased with ages. This was demonstrated by the concrete cubes cast with uncontaminated marine sand (controlled cubes) as shown in Figs. 1 and 2. At 7 day, the uncontaminated cubes attained 57.7% of their 28 day compressive strength. Also, at 14 day and 21 day, the compressive strength rose to 90.7% and 96.8% of its 28 day strength respectively. These observed variations in compressive strength were similar to those suggested by British Cement Association (2001). 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. Beyond 28 day, the uncontaminated cubes compressive strength was still rising, but at a slower rate. For instance, at 58 day, 88 day, 118 day and 148 day, the compressive strengths were 106.9%, 108.1%, 114.5% and 128.2% of the 28 day strength respectively. These results were slightly similar to those obtained by Choo et al (2001). They observed extra compressive strengths over 28 day strength of 10% and 20% at 2 months and 6 months respectively.

Generally, for uncontaminated fine sand, cement hydration will continue for a long period of time. Initially, the rate of hydration will be very fast leading to rapid gaining in concrete compressive strength. But with time, lesser cement particles would remain for hydration, hence the reduction in the rate of strength development occurs.

The behaviour of compressive strength of concrete cubes cast with diesel oil contaminated sand was quite different from those of controlled cubes as shown in Fig. 1. In all the three sets of cubes investigated for diesel oil contamination, there were initial rapid increase in compressive strengths development up to 28 day of concrete casting. Between 28 and 58 day, the rate of strength development continues even though still increasing the rate 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 as shown in Fig. 1. As revealed in Table 1, at 28 day, the cubes compressive strengths were 24.0, 23.1 and 19.2 N/mm^2 for 2%, 5% and 10% diesel oil contamination respectively. This trend was noticed throughout in Table 1. In comparison with the controlled cubes compressive at 28 day, theses values are equivalent to 96.8%, 93.1% and 77.4% respectively.

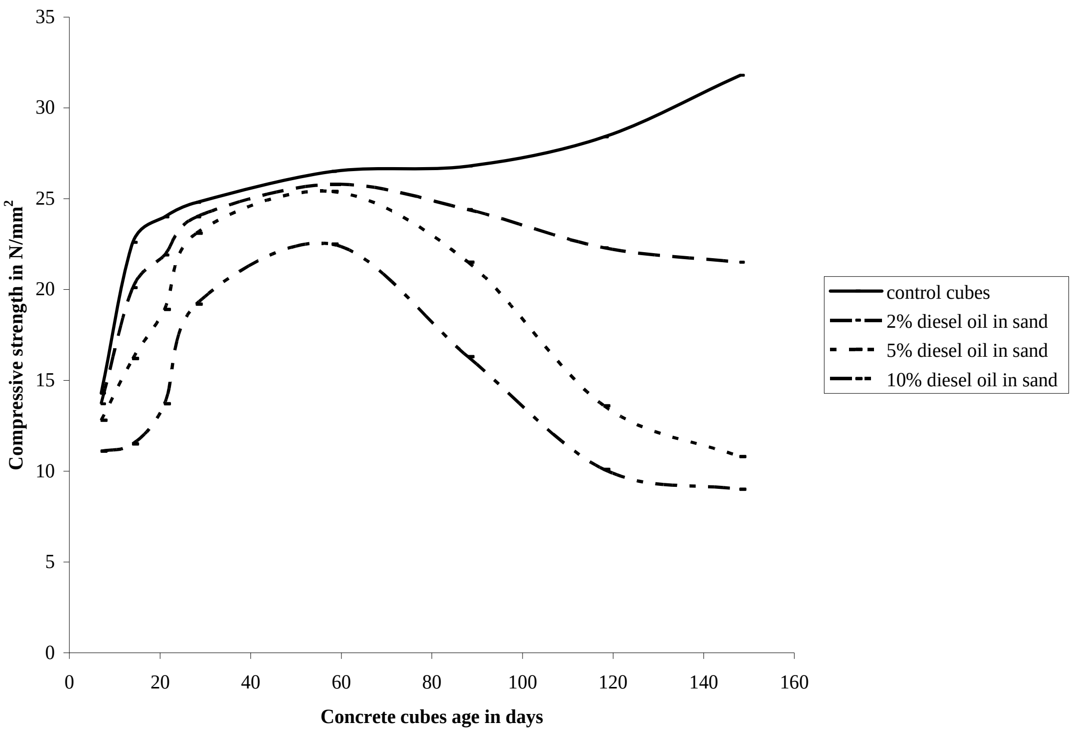

Fig. 1. Variations of compressive strengths of diesel oil contaminated concrete with age.

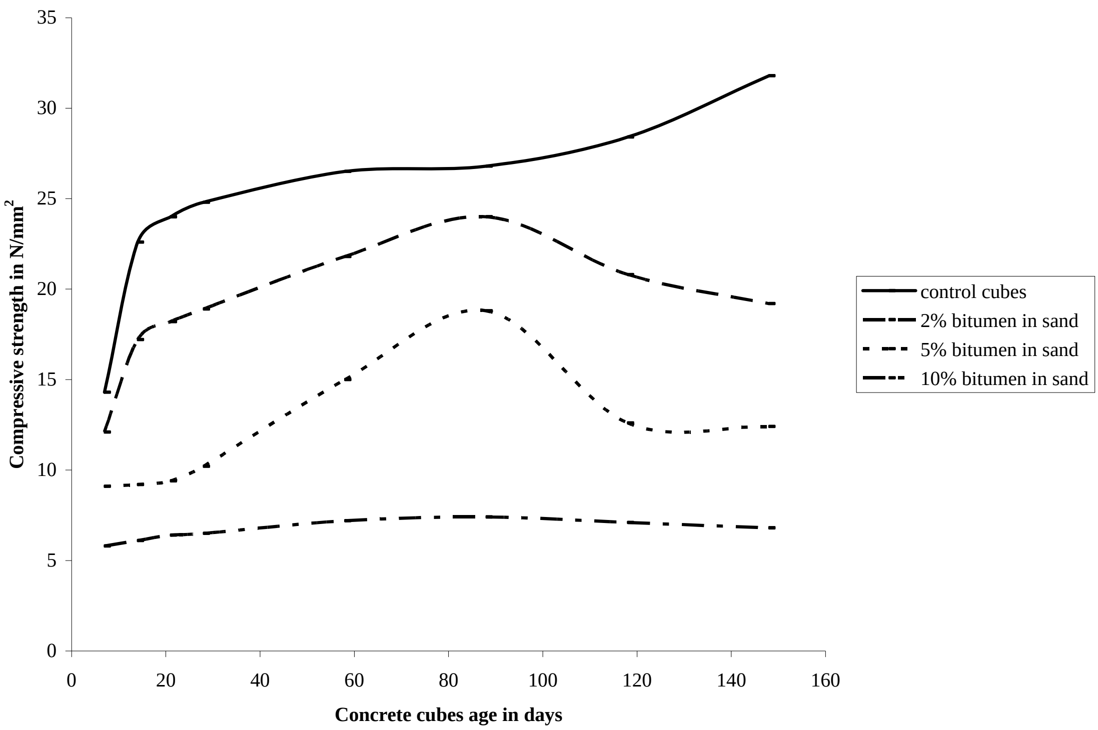

Fig. 2. Variations of compressive strengths of cut-back bitumen contaminated concrete with age

Table 1
Mean compressive strengths of cubes cast with both contaminated and uncontaminated marine sand

Testing days	Control cubes	Diesel oil contaminated sand			Cut-back bitumen contaminated sand		
		2%	5%	10%	2% 10%		5%
7	14.3	13.7	12.8	11.1	12.1	9.0	5.8
14	22.6	20.1	16.2	11.5	17.2	9.2	6.1
21	24.0	21.9	18.9	13.7	18.2	9.4	6.4
28	24.8	24.0	23.1	19.2	18.9	10.1	6.5
58	26.5	25.8	25.4	22.5	21.8	15.0	7.2
88	26.8	24.4	21.5	16.3	24.0	18.8	7.4
118	28.4	22.3	13.6	10.1	20.8	12.6	7.1
148	31.8	21.5	10.8	09.0	19.2	12.4	6.8

All values are in N/mm^2

Similar trend of increase in initial compressive strength development up to 88 day of concrete cubes production was noticed for all cubes cast with cut-back bitumen contaminated sand. Beyond 88-day, reduction in cubes strengths was observed. Referring to Table 1 and Fig. 2, the higher the percentage of diesel oil present in sand, the lower was the observed compressive strength with ages. The 28 day compressive strengths of cubes made with 2%, 5% and 10% cut-back bitumen contaminated sand were 76.2%, 40.7% and 26.2% respectively of those of controlled cubes.

The concrete compressive strength development depends to a large extent on cement hydration and aggregate – cement paste bond. In presence of water, the cement particles hydrated formed a firm called hydrated cement paste. The cement paste formed physical bond with both fine and coarse aggregates which resulted to concrete strength. Initially, not all cement particles hydrated. The quantities involved in hydration process in the first few days were much. As such the rate of hydration was very high, but gradually reduced as less unhydrated cement particles were present in the controlled cubes.

The surface areas of sand particles were coated with oil, physical bond formation between cement paste and aggregate (fine) was hindered. The higher the quantity of oil or bitumen present, the higher the barrier to the formation of physical bond responsible for concrete strength would be. The presence of oil or bitumen firm around the fine aggregates was responsible for the lower rate of strength development in concrete cubes cast with either diesel oil or bitumen contaminated marine sand. 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 oil; notwithstanding increase in strength development rate still occurred. This account for the observed increase in the compressive strength of both diesel oil and bitumen contaminated concrete cubes up to 58 and 88 days of concreting respectively. Beyond 58 and 88 days of concreting, the accumulation of oil and bitumen in concrete has formed thick barrier around cement paste and aggregates in concrete cubes. This action reduced the rate of bond formation between cement paste and aggregates, which account for the reduction in compressive strength observed.

During hydration heat was a by-product which reduced the covering produced by diesel oil around sand particles. In contrast, the heat of hydration effect on bitumen covering around sand particles was insignificant. The above reasons accounted for higher in values of compressive strengths of concrete cubes made with diesel oil contaminated sand over those of bitumen in all cases considered. In addition, the viscosity of diesel oil is lower than that of cut back bitumen.

4.0 Conclusions

The impact of bitumen and diesel oil contaminated sand on concrete compressive strengths was investigated. The following facts emerged:

1. On comparing with controlled concrete cubes, presence of diesel oil and bitumen of any proportion in sand resulted in concrete of lesser compressive strengths. This revealed clearly that diesel oil and bitumen are compressive strength inhibitors in concrete production.
2. The 28 day compressive strengths of concrete made of contaminated sand of 2 to 10% diesel oil were in the range of 96.8 to 77.4% of uncontaminated sand. Likewise, those of bitumen are in the range of 76.2 to 26.2%. The higher the percentage of oil in sand, the lower the compressive strengths obtained.
3. A little quantity of diesel oil such as 2% brought about 3.2% reduction in the 28 day compressive strength of concrete. Also, beyond 58 days of concreting, drastic reduction in strength occurred. It follows that diesel oil and bitumen in small proportion must be properly evaluated before using such material for concrete production.

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