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The Impact of Crude Oil Contaminated Natural Sand on Polymer Concrete

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Abstract

The mechanical properties of three Polymer Concretes (PC's) made from unsaturated polyester resin and Natural sand from Niger Delta region of Nigeria contaminated with crude oil were analyzed to determine their suitability for use as materials for local civil construction ,material. The first, Polymer Concrete (PC1), a control composite was made with 360g of polyester resin and 2640g of uncontaminated natural sand, while the second Polymer Concrete (PC2) and the third (PC3) were made with 360g of polyester resin and 2640g of sand contaminated with 50 and 100ml of crude oil respectively. The concretes were investigated after eleven days of curing under ambient temperature to ascertain the impact of crude oil contamination on the mechanical properties of the concretes. PC1made from unsaturated polyester resin and natural sand showed higher compressive strength of 20KN/mm^2 confirming its suitability in civil construction work for columns, beams, high impact resistant materials, etc. The result showed a lower compressive strength of 10KN/mm^2 and 6KN/mm^2 for PC2 and PC3 respectively, made with crude oil contaminated sand. The reduced compressive strength indicates the formation of thermoset composite material with a weak three dimensional network structure resulting from the impact of crude oil contamination on the binding effect of unsaturated polymers and sand in polymer concrete currently investigated as alternative to low cost housing material in the Niger Delta Region of Nigeria and alternative building material in areas prone to earthquakes. The results underscore the need for a proactive action towards elimination of crude oil contamination of natural sand.

Keywords: Polymer Concrete, Crude oil, Weak 3-D network structure, Compressive strength, Niger Delta Region

Introduction

Hydrocarbon leaks and spills have become of a great concern in most of the oil producing countries of the world. The effect of these leaks and spills on the environment cannot be overlooked or disregarded. One of such effect is that they cause a change in the properties and behaviour of soils (natural sand), (Akinwumi et al, 2014). These soils are of great importance in production of various engineering structures at both small and large scale productions. Natural sand is one of the major raw material in production of concretes especially Polymer concretes.

Polymer concretes (PC) is a composite material in which thermoset resin binds together natural aggregates, such as sand or gravel. Catalyst and accelerators are added up to the resin before mixing with inorganic aggregates, in order to initiate

the polymeric curing. In this type of concrete, absence of water is a basic necessity as it inhibits the curing of the concrete. (Izionworu & Dagde, 2014) (ACI, 1986).
Typical resins used in polymer concrete are polyester, epoxy and acrylic thermoset resins. They have been used for various end products. However, polyester is the most used mainly for economic reasons. (Izionworu & Dagde, 2014).

Resins concrete have good mechanical properties such as high compression, strength and high durability in terms of fatigue and corrosion resistance. Its permeability to liquids is generally very low and its curing times are quite fast.Polymer concretes are applied for industrial flooring, retouching of damaged concretes structures and underground pipes. In comparison with convention Portland cement concrete, polymer concrete offers many advantages such as: High strength, better chemical resistance and improved toughness, (Ohama, 1997).

Use of polymer resins instead of the traditional Portland cement as binder in making concretes helps obtain series of interesting properties. While some researches have used natural fibers to reinforce polymer composites as was the case in the research conducted by Peijs et al (1998) others like Singla and Chawla (2010) researched on the Mechanical Properties of Epoxy Resin – Fly Ash Composite in sea vessels underscoring the excellent mechanical properties of the resulting composite. Bhandakkar et al (2014) elucidated that Epoxy glass fiber laminate composite (PMCs) are also finding increasing applications in aerospace and automobile industries because of its high strength to weight ratio and resistance to aqueous environment. Bhandakkar et al (2014) concluded that additions of particulate reinforcements in the polymer matrix improve the Interlaminar Shear Strength and Interlaminar Fracture Toughness of the composites. Ikran and Munir (2012) modified Diglycidyl ether of bisphenol-A (DGEBA), by incorporating the hydroxyl terminated polybutadiene (HTPB) based prepolymer using isophorone diisocyanate as a coupling agent. The resulting mechanical, thermal and thermo-mechanical properties showed that the tensile strength, toughness, ductility and impact strength of the modified cured system were successfully increased at some optimum HTPB contents without affecting the inherent thermal and thermo-mechanical stability associated with DGEBA resin system. This advances leading to materials with desirable properties find use in other varied applications such as:
Production of industrial tanks, intended for electrolysis of non-ferrous metals
Production of catch basins and channels to drain aggressive industrial wastewater.

These applications make polymer concretes important to the field of engineering, hence the need for intensive studies on the material.

Since there is increasing use of polymers concrete in recent times in engineering structures especially in a bid to developing low cost housing this study focused on examining the impact of contamination of natural sand with crude oil. This situation is common in the Niger delta region of Nigeria where this composite would very useful.

Materials and Method

Materials

The materials employed in this research were as follows: Unsaturated Polyester resin supplied by Daily Polymer Limited. Polyester resins having a modulus of

3.42Gpa with a density of 1100kg/m3. The Catalyst (Methyl Ethyl Ketone peroxide) was from the stock supplied by Keum Jung Akzonobel Peroxide Limited was used as the initiator. The accelerator was supplied by Daily Polymer Limited. The crude oil was sourced from samples sent in by operators of joint ventures between Oil and Gas firms and Nigeria National Petroleum Corporation. (NNPC).

The natural sand was from Ochocho stream in Mgbuitanwo Emohua local government area of Rivers state. A Niger Delta region of Nigeria. The sand uniformity was achieved by using a 200µm sieve as was the case in a recent research work by Izionworu and Dagde, 2014; Reis and Ferreira, 2004 & 2011.

Mirror glaze supplied by Meguiar Inc. USA was used as mold release.

The natural sand was artificially contaminated with different quantities of crude oil through a physical Artificial Contamination process.

Equipment

The equipment used as listed below are in the Civil Engineering Laboratory of Rivers State University of Science and Technology, Port Harcourt, Rivers State, Nigeria

- Crushing Machine manufactured by Engineering Laboratory Equipment Limited (ELE), see Figure 2.1
- Avery weighing balance seen in Figure 2.2
- Vibrating machine see figure 2.3
- Cube Mold (100mm x 100mm x 100mm) see Figure 2.4
- Locally fabricated hand Mixer
- A bowl
- 200µm
- Trowel

Figure 2.1: Crushing Machine manufactured by Engineering Laboratory Equipment Limited (ELE)

Figure 2.2: Avery weighing balance

Figure 2.3: Vibrating machine

Figure 2.4: Cube Mold (100mm x 100mm x 100mm)

Method

The formation of the composite is as seen in Table 2.1, two practical test were carried out, using polymer resin with natural sand (uncontaminated) for the first test (PC2) while polymer resin and contaminated natural sand were used in test two (PC2).

Table 2.1 Components of the composite

Test Series	Components of the Composite		
	Polymer Resin	Uncontaminat-ed Sand	Contaminat-ed Sand
1	√	√	
2	√		√

(Izionworu & Dagde, 2014).

In each test, the cube-compressive test slum, that is, that workability of concrete was used as detailed below.

Density = $$\frac{Mass}{Volume}\ in\ \frac{gm}{Cc}\left(\frac{g}{cm^3}\right) \quad (1)$$

Mass of concrete = $$\frac{KN}{9.81N} \quad (2)$$

Absolute volume of laboratory mold is 0.00115.

The ratios of components of the polymer concrete were based on the approximate weight of 3kg for a cube mold of 100mm x 100mm x 100mm and derived with the ratio of Table 2.2. Each material for the polymer concrete was weighed using the average weighing balance and thoroughly mixed in the locally made hand mixer. The unsaturated polymer resin for each test was measured and poured into a bowel and the accelerator and catalyst in a ratio of 2:1 was added to the polyester resin and thereafter thoroughly mixed. The catalyst, (MEKP) drove the reaction. Then the pre-polymer undergoing polymerization and cross-linking was poured into the measured natural sand (either contaminated or uncontaminated).

Table 2.2 Weight (%) Of Components

TEST SERIES	COMPONENTS OF THE COMPOSITE		
	Polymer Resin	Uncontaminated Sand	Contaminated Sand
1	12	88	
2	12		88

(Izionworu & Dagde, 2014).

The polymer mortar was thoroughly mixed and poured into the 100mm x 100mm x 100mm mold which was glazed with mirror glaze to facilitate release of the polymer concrete, (PC) from the mold after curing. The filled mold was then placed on the vibrating machine which ensured complete filling of the mold preventing any void. These process was repeated for the formulation of the polymer concrete (PC) for test two and three. The polymer concretes were allowed to cure (polymerize) in ambient temperature for a minimum of eleven days.

Characterization of the Polymer Concrete

Compressive Strength

The compressive strength test was conducted using ELE concrete compression machine by loading of the test specimen, between the load surface of the testing machine and increasing compressive load applied to each specimen until failure or crushing occurs.

The compressive strength is calculated using

$$\sigma = \frac{F}{A} or \ \frac{P}{A} \qquad (3)$$

Where
S = Compressive strength
F = Maximum load recorded
A = Cross-sectional area of cube specimen

Density

The density of the PC was obtained by weighing the specimen and applying the relationship between density and weight.

$$\text{Density} = \frac{Mass}{Volume} \, in \, g/cm^3 \quad (4)$$

Results and Discussion

Compressive Strength Tests

The crushing strength test was carried out to determine the compressive strength of the different polymer concretes (PC's).the polymer concrete are defined thus:

Sample 1: (PC1): Polymer concrete made of pure natural sand, polyester resin, accelerators and catalyst only.

Sample 2: (PC2): Polymer concrete made of crude oil contaminated sand (50ml crude oil contamination for 2.640kg of sand), polyester resin, catalyst and accelerators.

Sample 3: (PC3): Polymer concrete made of crude oil contaminated sand (100ml crude oil contamination for 2.640kg of sand), polyester resin, catalyst and accelerators.

The crushing test results on PC1 is shown in Table 3.1. Also, the crushing strength test result on PC2 composed of unsaturated polyester resin, natural sand (2.640kgkg) contaminated with 50ml of crude oil is shown in Table 3.2. Similarly, the crushing strength test result on PC3 composed of unsaturated polyester resin, sand (2.640kg) contaminated with crude oil (100ml), catalyst and accelerator is shown Table 3.3.

Table 3.1: Compressive Strength and Other Characteristics of PC1:

Material identifica-tion	Size of cube/ block (mm)	Weight of specimen (kg)	Load (KN)	Stress (N/mm^2)	age (days)
PC1	100X100X100	2	200	20.00	11

Table 3.2: Compressive Strength and Other Characteristics of PC2

Material identifica-tion	Size of cube/ block (mm)	Weight of specimen (kg)	Load (KN)	Stress ($N/mm)^2$	Age (days)
PC2	100X100X100	2.1	100	10.00	11

Table 3.3: Compressive Strength and Other Characteristics of PC3

Material identifica-tion	Size of cube/ block (mm)	Weight of specimen (kg)	Load (KN)	Stress (N/mm^2)	Age (days)
PC3	100X100X100	2.2	60	6.00	11

Table 3.4 gives a summary of the compressive strength and the final weight and density of the polymer concretes produced. The result clearly indicates that PC1 has the highest compressive strength of 20N/mm^2 where the compressive strength of PC2 which has a lower crude oil contamination also clearly shows a higher strength than PC3 with a higher contamination of crude oil (100ml). The low strength of PC2 and PC3 when compared with PC1 shows the very high extent, crude oil contamination influences the mechanical properties of polymer concretes/composites; and as the contamination was increased from 50mls in the case of PC2 to 100ml for PC3 the compressive strength speedily reduced to 6N/mm^2 from 10 N/mm^2. Since the three samples were cured under same condition and of the same age (11 days); it follows that the difference in compressive strength was influenced by contamination. It is practicable to draw an analogy for the resulting decrease in compressive strength due to contamination of sand used in this research by crude oil to the influence of styrene concentration on the miscibility and mechanical properties of polymerization of unsaturated polyester resins. Sanchez et al (1999) demonstrated that increase of styrene content in unsaturated polyester resins results in broadening of the glass transition which according to them is associated with the development of the microenvironments with different compositions and crosslinking density. It is instructive to note that the resulting polymer consist of two phases rich in polystyrene and unsaturated polyester phase. In that research Sanchez et al (1999), suggested that increase in styrene concentration causes a drop in the crosslinking density which determines the mechanical properties of the resulting polymer. It follows conversely that the presence of crude oil depending on the concentration introduces areas of weak interaction for reaction between the unsaturated polyester resin and sand in the suggested schematic structure of the polymerization process of Figures 3.1 to 3.2 below. These areas weaken the network linkages of the resulting structure.

Table 3.4: summary of the Compressive strength and other characteristics of PC's

Material identification	Size of cube/block (mm)	Weight of specimen (kg)	Density of specimen (g/cc)	Load (KN)	Stress (N/ mm^2)	Age (days)
PC1	100X100X100	2	2	200	20.00	11
PC2	100X100X100	2.1	2.1	100	10.00	11
PC3	100X100X100	2.2	2.2	60	6.00	11

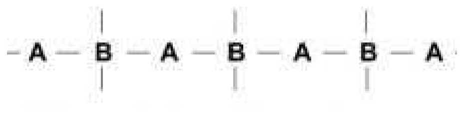


Figure 3.1: an idealized chemical structure of a typical polyester

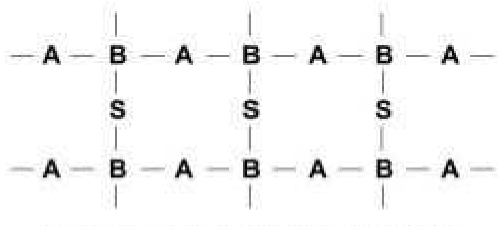
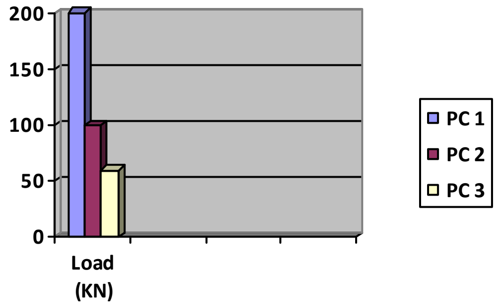
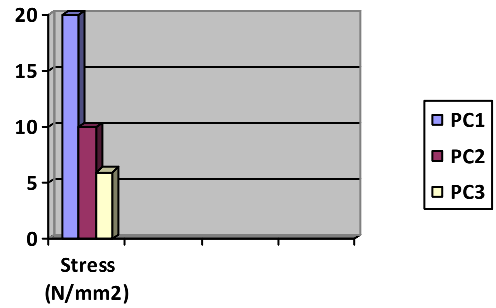


Figure 3.2: Schematic representation of cured polyester resin





Conclusions

Polymer concrete (PC) was successfully manufactured using unsaturated polyester, resin, uncontaminated natural sand, and sand contaminated with crude oil (for PC2 and PC3). The PC's were subjected to compressive strength test after eleven (11) days of curing. The result shows that crude oil contamination reduces the compressive strength of polymer concrete, by affecting the 3-D cross linking of the polymer or its curing. As seen in this research experimental result, increased contamination of sand with crude oil lead to a reduction in the compressive strength suggesting that crude oil interphase reduced the bonding sites of the 3-D network structure of the resulting thermoset composite material from the polymerization of the unsaturated polyester resin. This study indicates that silicon plastics made of Niger Delta sand can be impacted on losing its water resistance property if the sand is contaminated by crude oil. It is of interest to note that in polymer composite/concrete production; proper care should be taken to use sand free from crude oil contamination of any form, since they have been proven to show great deviation when slightly contaminated. Also, owing to the possible danger associated with structures made of weak Polymer Concretes effort must be made to reduced oil spillage and proper clean-up at the event of a spill. The obvious impact of crude oil contaminated sand on the compressive strength property of polymer concrete underscores the need for good environmental protection policies to be enforced globally in weak economies, with the Niger Delta region of Nigeria as a case in point to discourage sand (land) contamination so as to have purer (uncontaminated) sand in the local environment for manufacturing and application in polymer concrete and by extension silicon plastics.

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