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CHARACTERIZATION OF POLYMER CONCRETE MADE OF COCONUT/GLASS FIBERS AND NATURAL SILICA SAND FROM NIGER DELTA, NIGERIA

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Abstract— In this research the mechanical properties of four series of different weight ratios of Polymer Concrete made from a polymer-unsaturated polyester resin and aggregates – natural silica sand from the Niger delta region of Nigeria and others made of same polymer, sand and reinforced with fiberglass, coconut fiber and fiberglass combined with coconut were investigated for characterization and determination of their suitability as materials for civil construction. Compressive strength tests were performed at ambient temperature. After different ageing, the mechanical behavior of the polymer concrete made of polymer and aggregates alone were compared with that of the same polymer concrete reinforced with fiberglass, coconut fiber and a combination of both fibers. The polymer concrete made from unsaturated polyester resin and natural silica sand from the Niger Delta region of Nigeria showed a remarkable compressive strength of $30N/mm^3$ which makes it suitable for use in civil construction work-columns beams and floors of building. The result showed a decrease in compressive strength for polymer concretes with fibers after the resin percent by weight was reduced indicating the influence of the polymer matrix in the polymer concrete.

Index Terms— Polymer Concrete, Fibers, Reinforcement, Filler material, Compressive strength,

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1 Introduction

Polymer concrete (PC) is a composite material in which thermoset resin bind together natural aggregates, such as sand and gravel. Catalyst and accelerators are added up to resin before mixing with inorganic aggregate, in order to initiate the polymeric curing. In this type of concrete, water is completely absent as it inhabits the curing of the concretes [1]. Therefore, unlike a mortar mix made up of water, cement and aggregates cured to form a cement concretes, this is a water free concrete [2]. Polyester, epoxy and acrylic thermoset resins are the commonly used resins in PC's. Polyesters are the most used mainly for economic reasons. It has been identified that resin concretes 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 [2]. Polymer concrete has previously been mainly used for industrial flooring, retouching of damaged concrete structure and underground pipes. Today the industrial applications of polymer concretes are growing steadily as they are used as an alternative to cement concrete in many applications. In comparison with conventional port-land cement concrete Polymer Concrete offers many advantages, such as higher strength better chemical resistance and improved fracture toughness [3].

For the past 50 years or more, the development of polymer concrete has been conducted in various countries. Today polymer concrete is used for furnishing work last-in-place application, precast products, highway – pavements, bridge decks, waste water pipes and even decorative construction panels [3]. The good mechanical and corrosion properties of such concrete allow thinner cross-sections and lower cover depths in reinforced concretes reducing transport cost and handling risks. Unlike conventional materials (eg, steel) the properties of the composite material can be designed considering the structural aspect. The design of a structural component using composites involves both material and structural design. Composite properties (eg, stiffness, thermal expansion etc) can be varied continuously over a broad range of values under the control of the designed. Careful selection of reinforcement type enables finished product characteristics to be tailored to almost any specific engineering requirement. Whilst the use of composites will be a clear choice in many instances, material selection in others will depend on factors such as working lifetime requirements, number of items to be produced, complexity of product shape, possible savings in assembly costs and on the experience and skills of the designer in tapping the optimum potential of composites in conjunction with traditional materials. Coconut (coir) fiber is one of the readily available, non-wood natural fiber. Therefore, it is really useful to find the application for these materials, which will surely lessen environmental problems related to the disposal of coconut fiber waste and produce materials that could offer a favorable balance of quality, performance and cost. Thus, it is necessary to check this properties of the material before the material can be broadly used as a building material. The use of coconut fiber from the dispose of coconut

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shell could be a valuable material in the formation of a composite material that can be used as an internal panel wall in housing construction or as bearing in structural reinforcement of houses. Coir like other natural fibers are not expensive when compared to man-made fibers and as indicated in past and recent research [4], [5], natural fibers have emerged as potential alternative for glass fibers in engineering composites. The aim of this research is to produce and characterize polymer concrete (PC) using fibers from locally sourced coconut as reinforcing/filler materials. The resulting PC will be compared with PC composed of natural sand alone and that reinforced with fiber glass. The objectives of this work are (1) the fabrication of coconut fiber reinforced unsaturated polyester based composite. (2) Evaluation of the mechanical properties with particular reference to the compressive strength and, (3) to develop new class of composite by incorporating locally sourced coconut fiber reinforcing phases into a polymeric resin. (4) Also, this work is expected to introduce a new class of low cost composite material that might find application in housing projects locally. Although thermoset resins are quite expensive compared to Portland cement based materials [5], research is on to introduce locally sourced cellulous materials to make them cheaper.

2. MATERIALS AND METHODS

A: Matrix

Unsaturated polyester resin supplied by Daily Polymer Corp Limited was used. The resin has a modules of 3.42 Gpa with a density of 1100kg/m^3. Catalyst (Methyl Ethyl Ketone, MEK) supplied by keum jung Akzonobel Peroxide Limited and Accelerator supplied by Daily Polymer Corp. Limited were used.

B: Fibers

The fibers used for the fabrication of the composites are Coconut fiber a natural fiber also referred to as coir with density of 1.2gm/cm^2, tensile strength of 175MPa and Young Modulus of 5GPa [5], and Fiber glass mat supplied by Daily Polymer corp Limited. The fibers were chopped into sizes of 6mm using a scissors.

C: Natural sand.

Fresh natural silica sand from the Niger delta region of Nigeria was used which is a deviation from the normal use of foundry sand [6], [7]. The sand was of uniform particle size, with an average of 200μm.

D: Mold release

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

E: Equipment

The following equipment in the Civil Engineering Laboratory of Rivers State University of Science and Technology, Port Harcourt, Rivers State, Nigeria were used: Crushing machine, Fig. 1, manufactured by Engineering Laboratory Equipment Limited, (ELE). Avery weighing balance, Fig. 2, Vibrating machine, Fig. 3, Cube mold (100mm x 100mm x 100mm), Fig. 4. Locally fabricated hand mixer, A bowl , and Trowel.

Fig. 1: Concrete Compression Machine, Engineering Laboratory Equipment (ELE)

Fig. 2. Avery Weighing Balance

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Fig. 3. Vibrating Machine

Fig. 4. Cube Mold

***F:* Method and Experimental Process**

The formation of the composite is as seen in Table 1[6]. Four practical tests were carried out using polymer resin with natural alone for Polymer Concrete 1 (PC1), polymer resin, natural sand and fiber glass for the second test (PC2), polymer resin, natural sand and coconut fiber was used for PC3, while polymer resin, natural sand, fiberglass and coir were used in test four for PC4.

Table1: Component of Composite

Test Series	Components of the composite			
	Polymer Resin	Natural Sand	Fiberglass	Coir
1	√	√		
2	√	√	√	
3	√	√		√
4	√	√	√	√

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

Density of concrete (Cement, sand and gravel) is 24KN/m³ [9],

$$Density = \frac{Mass}{Volume} \text{ in } \frac{gm}{cc} \quad (1)$$

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

Absolute Volume of Laboratory control mold is 0.00115

The ratios of the 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. Each material for the polymer concrete was weighed using the Avery weighing balance and thoroughly mixed in the locally made hand mixer. The unsaturated polyester resin for each test was measured and poured into a bowl and the accelerator and catalyst in a ratio of 2:1 were added to the polyester resin and thoroughly mixed. The catalyst, MEK, drives the reaction. Then the pre-polymer undergoing polymerization and cross linking is poured into the measured natural sand.

Table2: Ratios of composite formulation

Test Series	Weight % of Components			
	Polymer Resin	Natural Sand	Fiberglass	Coir
1	12	88		
2	10	88	2	
3	10	88		2
4	10	88	1	1

The polymer mortar is thoroughly mixed and poured into the 100mm x 100mm x 100mm mold already glazed with mirror glaze to facilitate release of polymer concrete, (PC) from the mold after curing. The filled mold is placed on the vibrating machine which ensures complete filling of the mold, preventing any void. The process is repeated for other composite formulation for the polymer concrete (PC) of tests 2, 3 and 4 of Table 2. The PC's were allowed to cure (polymerize and cross link) in ambient temperature for a minimum of seven days.

3. CHARACTERIZATION OF THE POLYMER CONCRETE

***A:* Compressive Strength**

The compressive strength test was conducted using ELE concrete compression machine (Figure1) by loading of the test specimen between the load surface of the testing machine and increasing compressive load was applied to each specimen until failure or crushing occurred. The compressive strength is calculated using:

$$\sigma_c = \frac{F}{A} \quad (3)$$

Where, σ_c is the Compressive Strength F is Maximum Load recorded, and A is the Cross-sectional area of cube specimens.

B: **Density**

The density of the Polymer Concrete is obtained by weighing the specimen and applying (1) above.

4. RESULT AND DISCUSSION

The result of the experiments conducted in the study of polymer concrete using unsaturated polyester resin, natural sand reinforced with fiberglass and coconut fiber are as presented.

A: **Compressive Strength Test**

The crushing strength test was carried out to determine the compressive strength of the different polymer concretes, (PC's). The PC identified as PC1 was composed of unsaturated polyester resin, natural sand, catalyst and accelerator and the result is as seen in Table 3. The crushing strength test on polymer concrete, PC2 composed of unsaturated polyester resin, natural sand, fiberglass as reinforcement, catalyst and accelerator is as shown in Table 3. Polymer concrete PC3 composed of unsaturated polyester resin, natural sand, coconut fiber as reinforcement, catalyst and accelerator has the crushing strength test result also shown in Table 3. Table 3 also shows the crushing strength test result for polymer concrete 4, PC4, composed of unsaturated polyester resin, natural sand, fiberglass and coconut fiber as reinforcement, catalyst and accelerator. The weight and density of each of the manufactured PC's is also shown in Table 3.

Table 3: Compressive strength, and Density of polymer concrete.

PC	Size of block (mm^3)	Wt (kg)	Density (gm/cc)	Age (Days)	Load (KN)	Stress (N/mm^2)
PC1	$1x10^6$	2.2	2.2	11	300	30.00
PC2	$1x10^6$	1.8	1.8	7	100	10.00
PC3	$1x10^6$	1.6	1.6	7	10	1.00
PC4	$1x10^6$	2.2	2.2	19	80	8.00

The results indicate that PC1 has the highest compressive strength of $30N/mm^2$ when compared with the compressive strengths of PC2, PC3 and PC4, which are 10, 1 and $8N/mm^2$ respectively. PC2 which has fiberglass as reinforcement had a higher compressive strength when compared with PC3 which has coir as reinforcement. While the higher compressive strength of PC4 which was a blend of fiber glass and coir fiber when compared with PC3 may have been influenced by the age, i.e. the curing duration of the PC. Overall, PC1 with compressive strength of $30N/mm^3$ after 11 days cure shows a tendency for its suitability as a structural element when compared with the standard compressive strength of concrete made of cement matrix or commercial concretes which has compressive strength of $30N/mm^2$ within 7 days of curing according to FRN National building code,[9]. PC3 was observed to have the least weight and density, partly because of the light weight of the fibers used as reinforcement and also because of the possibility of void in the composite. PC1 and PC4 which has very close condition of production in terms of weight, density and binder ratio with the exception of the weight percent of the unsaturated polyester resin in the PC (Table 2) and curing or aging duration of 11 and 19 days respectively, has a remarkable difference in compressive strength indicating a seeming level of structural weakness of the PC's with fillers. However the key component, which is the resin is more in PC1 by 2% by weight. This percentage increase of the pre-polymer which acts as the aggregates binder upon complete polymerization increases the binding of the polymer concrete, leading to 200% difference in the compressive strength of PC1 and PC2 as seen in Fig. 5. This difference is as a result of the extent of three-dimensional polymer network [7] in PC1 when compared with PC2.

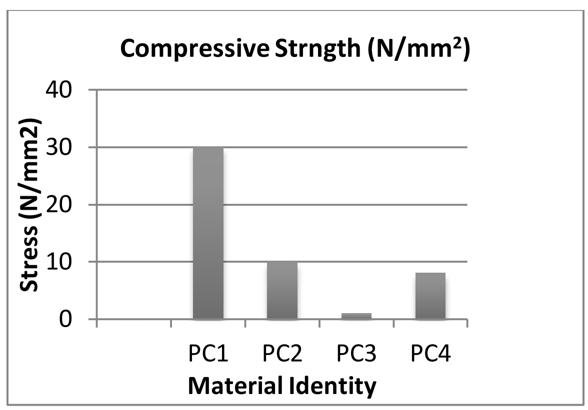

Fig. 5. Compressive Strength of Composites

5. CONCLUSION

Polymer concrete (PC) was successfully manufactured using unsaturated polyester resin, natural sand from the Niger delta region of Nigeria, and fiber. The characterization result of PC1, Table 4.1, shows that it will be suitable as structural, demarcation for house construction. However, the low

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compression strength of the PC's having glass fiber and coconut fibers, leaves much to be desired hence the need for the recommendations that follows. The maximum load they were able to carry, that is 100KN, 10KN and 80KN is very small when compare to the load a typical safe civil structure should carry. It is clear that the bonding between the unsaturated polyester resin which is a pre-polymer and the fibers were weak. From the findings in the research we recommend that further research on the subject matter be conducted and the test carried out for different durations of uniform curing periods. We could develop a PC that will be suitable for building of house reducing the cost of building houses.

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