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Investigation on the Strength Characteristics of Polyster+ Polymer Concrete

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***Abstract*— Polystyrene which is also called Styrofoam have a lot of use for traders especially for packaging of fragile electrical equipment. However, its disposer has been a major environmental and ecological problem. In this research, the polystyrene is used to make the polyster+ polymer and therefore, used to produce the polyster+ polymer composite when mixed with aggregates. The composite (mortar) was prepared without the addition of coarse aggregate. Various constituents by percentage proportion of resin to aggregate were tried and tested. The mix ratio of 1:5.7 (15% of binder to 85% of aggregate) gives the optimum strength characteristics and thus, its tensile, compressive and flexural tests for 7, 14 and 28 days were carried out. Further wok is however required to improve the early buckling failure of samples with resin content greater than 15% and also with the introduction of coarse aggregate in the concrete.**

Keywords—Polystyrene; Polymer Concrete; Compression; Tension; Flexure

I. INTRODUCTION

The high cost of building and construction materials in Nigeria and other developing countries have forced researchers into sourcing for cheaper materials to be used as a substitute for the contemporary construction materials in civil engineering construction. The Portland cement concrete has been in use over the years and has been very successful in achieving the basic requirement that is needed for civil engineering construction works; however, since the improvement of concrete by using polymeric materials was investigated in the 1960s, focus has been shifted to changing or substituting the binding material in the concrete which is the Portland cement to the polymeric material or resin. The polymeric resin is then mixed with mineral aggregates to form a composite material called polymer concrete. Polymer concrete has a lot of advantages over the Portland cement concrete some of which includes higher strength characteristics and a shorter curing period [1].

The world is beginning to embrace the use of polymer concrete in the construction industries due to its various advantages over the Portland cement concrete when compared together. Polymer concrete has characteristics which differ greatly depending on how they are prepared. Kirlikovali [2] described that the properties of polymer concrete differs depending on the content of the binding material, the size of the aggregate distribution, the content and the nature of the micro-filler and the condition of the curing process. Various resins or polymer can be used for the preparation of polymer concrete, with each having different characteristics which greatly influence the properties of the polymer concrete. The most commonly used and available resins in Nigeria are the unsaturated resins, epoxy resins, furan resins and the methyl methacrylate resins.

There are two types of polymer materials that are commonly used in concrete works. This include the polymer modified concrete and the polymer concrete.

Polymer modified concrete is further subdivided into polymer impregnated concrete and polymer cement concrete. Polymer impregnated concrete, just as the name sounds, is produced by impregnating pre-cast hardened Portland cement concrete with a monomer which is then converted into a solid polymer. The polymer cement concrete is produced by replacing part of the cement binder of the concrete mix by polymer resin (often in latex form). The polymer impregnated concrete and the polymer cement concrete both have higher strength characteristics, lower water permeability, better resistance to chemicals, and greater freeze-thaw stability than the common conventional Portland cement concrete.

Polymer concrete, or resin concrete is a special kind of concrete which consists of a polymer which acts as a binder which may be a thermoplastic or a thermosetting polymer, and mineral filler such as aggregates. The aggregate may be either or both fine aggregate (sand) and coarse aggregate (crushed stones, granite, gravel).

A. Polystyrene

Polystyrene which is also called Styrofoam has been greatly used in Nigeria as a packaging material such as packing electronics and other fragile materials. It is also used for appliance insulation, lightweight protective packaging, surfboards, foodservice and food packaging, automobile parts, roadway and road bank stabilization systems and more. Combining Polystyrene with various colorants, additives or other plastics, it is possible to

make appliances, electronics, automobile parts, toys, gardening pots and equipment and more.

Disposing polystyrene has been a great challenge in various households and communities as it is non-degradable and therefore causing environmental and health hazards. These deposition problems make researches to combine it with series of additive or chemicals that can dissolve them to form another but less environmental toxic compound and can easily be disposed.

Polystyrene has also been identified for its insulating and cushioning properties when it is made into a foam material, called expanded polystyrene (EPS). The polystyrene may contain about 95 percent air and has been widely used in civil engineering constructions due to its light weight to produce lightweight concrete. Various researchers have used polystyrene to partially replace coarse aggregate in concrete which will yield a low-strength light weight concrete of very low density. In order to produce concrete of considerable light weight, polystyrene is broken into aggregate sizes and used as partial replacement of aggregate in concrete, thereby reducing the unit weight of the concrete. Bischoff et al., [3] researched that using polystyrene as aggregate in concrete is possible as a light weight concrete. This concrete has a high-energy absorbing property which makes it suitable for use, thereby, for reduction for impact loading.

The aim of this project is to perform experimental studies on the strength characteristics of locally made polyester^{+} polymer concrete (mortar) and compare it with cement mortar. To achieve the objective of the study, compressive, tensile and flexural tests were carried out on the samples. An Investigation on the strength characteristics of the polyster^{+} polymer mixed with sand (fine aggregate) will be carried out in order to determine if the material is suitable and can be used for concrete works. The details of the materials used for these specimens and testing procedure incorporated in the test program are presented in the subsequent sections.

II. MATERIALS AND METHODOLOGY

The raw materials used for this project were locally available. These include the polyster^{+} polymer and sand (fine aggregate) without using coarse aggregate.

Since there is an absence of coarse aggregate in the test sample, the fine aggregate passing through sieve size 4.75mm according to IS sieve size is tested and the properties are tabulated in table 1;

TABLE I. PROPERTY OF SAND

Physical test on aggregate	Test result
Moisture content	6.38%
Specific gravity	2.6
Sieve analysis	Zone II

A. Polyster^{+} Polymer Concrete

The binder to be used as polymer for this research was prepared by dissolving polystyrene (Styrofoam) in a solvent to get polyster+ and stirred thoroughly for about 3 minutes.

The polyster+ resin was mixed with sand by weight in the proportions of 10:90% (1:9), 15%:85% (1:5.7), 20%:80% (1:4), 25%:75% (1:3) and 30%:70% (1:2.3) of polyster+ to sand respectively.

The sand was first spread on a clean tray and the polyester+ polymer was later added and mixed properly for about 2-5 minutes.

The samples were then casted and de-moulded after 24 hours of casting and subsequently cured by air (room temperature). It should however be noted that all these can only be done in area shielded from the scotching effect of the sun shine.

B. Cement Concrete (Mortar)

The same mix proportion was also used for the preparation of cement mortar by mixing with sand using a water cement ratio of 0.5 for all the proportions. The samples were casted and de-molded after 24 hours of casting and subsequently immersed in water for curing.

C. Immediate Strength gain (Stiffening)

After removal of the specimens from the moulds after 24 hours, it was discovered that the mix ratio of 1:2.3 (resin to sand) has a very poor stiffening process (even though it is has a great bonding) and cannot be moulded into large mass without failure i.e. it buckles down. The sand content is not enough and thus need to be increased. As the sand content increases for other mix proportion, its stiffening increases as well with lower bounding of the particles of the mix. The mix proportion of 1:9 have a very weak bounding of the sand and thus, it cannot withstand the test of time as it shrinks off as a result of the influence of too much sand. The mix proportion of 1:5.7 is now used for this project.

TABLE II. PROPERTY OF SAND

Mixing ratio (%)	Early strength gain
30:70	Very poor
25:75	Poor
20:80	Fair
15:85	Good
10:90	Fair

Since the mix proportion of 1:5.7 (binder to aggregate) shows improved strength (stiffening), its specimens were casted and tested using universal testing machine after 7, 14 and 28 days curing.

D. Testing

Three strength tests were carried out in this research work and a Universal testing machine of 300kN load capacity was used for this research with a loading speed of 50mm/min.

The compressive strength test was performed in accordance with BS 1881: Part 116 [4], while the flexural strength test was carried out in accordance with ISO 178:1993 [5] using specimens of length 300mm, thickness 100mm and height of 100mm and testing the sample on a universal testing machine. The split tensile strength test was done using a manual compression machine and was performed in accordance with ASTM D 695 M-91 standard using 200mm×100mm cylindrical mould [6]. The tensile strength is calculated from the formulae:

$$\text{Tensile strength} = 2P/(\bar{\lambda}DL) \ (N/mm^2) \qquad (1)$$

Where P = crushing load, D = diameter and L = sample length

III. RESULT AND DISCUSSION

Compressive, tensile and flexural strength at 7, 14 and 28 days were tested and tabulated below;

A. Compressive strength test

Fig. 1. Universal testing machine with compressive test cube

TABLE III. COMPRESSIVE STRENGTH

Binder	Compressive Strength (N/mm^2)		
	7 days	*14 days*	*28 days*
Polyster$^+$ binder	1.462	3.213	5.194
Cement binder	4.768	5.341	5.913

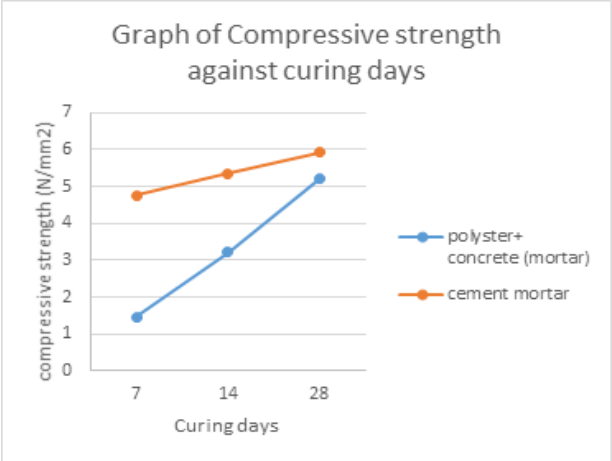

Fig. 2. Graph of compressive strength of cement mortar and polyster+ composite per day

B. Flexural Strength

Fig. 3. UTM with flexural test sample

TABLE IV. FLEXURAL STRENGTH

Binder	Flexural Strength (N/mm^2)		
	7 days	14 days	28 days
Polyster$^+$ binder	2.200	2.736	3.808
Cement binder	1.754	2.083	2.742

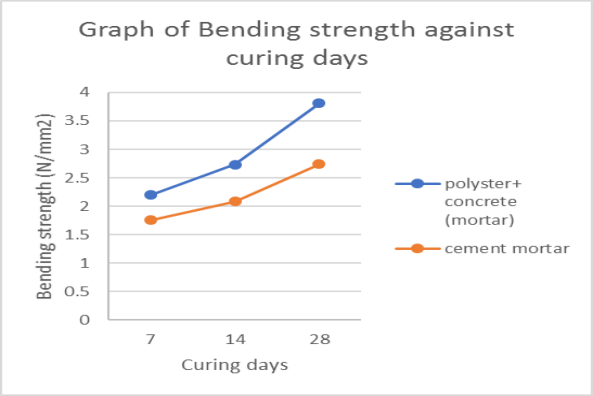

Fig. 4. Graph of flexural strength of composite per day

C. *Tensile Strength test*

TABLE V. SPLITTING TENSILE STRENGTH

Binder	Splitting Tensile Strength (N/mm^2)		
	7 days	14 days	28 days
Polyster$^+$ binder	0.240	0.807	1.94
Cement binder	0.670	0.756	0.830

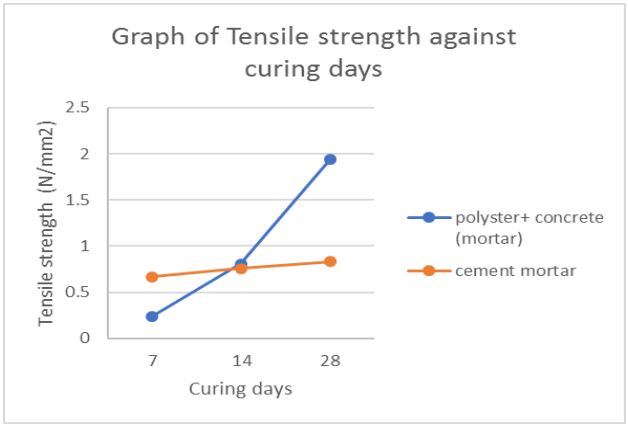

Fig. 5. Graph of tensile strength of composite per day

Various mix proportions of polyster$^+$ to aggregate were first tried and it was discovered that the resin content should not be more than 25% and not less than 10%, since concrete of more than 25% by weight of polyester$^+$ resin to fine aggregate has very low early strength (low curing) rate for moulded sample of large mass and thus falls on its own weight (buckles down). While the resin content of 10% to 90% by weight of polyster$^+$ to aggregate is too small (not enough to mix the sand properly), thus it has very strong early strength but little strength development over time.

The strength of the polyster+ polymer concrete increases with the advancement of age but decreases with increase in the percentage of the polyster+ binder used. That is, 30% and 25% of polyster+ binder has a very poor early stiffening process and the specimen therefore failed totally on its own weight immediately after de-moulding. 20% of polyster+ binder has a fair early stiffening process but shows a significant strength improvement over 28 days. 10% of polyster+ binder has too much of the sand and therefore shrinks away. At 15% of polyster+ binder, this has a very good early stiffening process and the strength increases with the advancement of age.

IV. CONCLUSION AND RECOMMENDATION

From the research carried out, the following conclusion can be made;

- Polyster+ polymer concrete can be classified as a light weight concrete since its density ranges from 1611 to 1698kg/m3.
- The average compressive strength of the polyster+ polymer concrete with 15% of the polyster+ binder was found to be 1.462N/mm2 at 7 days curing in air and increased appreciably to 5.914N/mm2 at 28 days.
- The average tensile strength of the polyster+ polymer concrete with 15% polyster+ binder was found to be 0.24N/mm2 at 7 days and increased with advancement of age to 1.94N/mm2 at 28 days.
- The average bending strength of the polyster+ polymer concrete was found to be 2.20N/mm2 at peak for 7 days curing and increased to 3.808N/mm2 bending strength at 28 days curing in air.
- The early strength development (stiffening) of the polymer concrete with mix ratio of 1:3 (resin to sand) and others with lower strength could be improved by using a perforated mould to allow easy airflow into the mould for curing improvement.
- In order to get higher compressive strength and fully utilize the advantages of the addition of coconut fibre, coarse aggregate should be added into the concrete to increase the strength of the concrete.
- The use of polyster+ as a resin in polymer concrete is advisable to be used under a monitored situation because it needs adequate monitoring and also improvements. It is therefore advisable to be made in a precast yard to be used as a precast element.

V. REFRENCES

[1] Martinez, B., Virgueras, S., Gencel, O., & Hagg-Lobland, H. Polymer concretes: A description and

methods for modification and improvement. Journal of Materials Education, 33(1-2), 37-52. 2011.

[2] Kirlikovali, E. Polymer/Concrete Composites - A review. Polymer Engineering and Science, 21(8), 507-509. 1981.

[3] Bischoff, P. H., Yamura, K. & Perry, S. H. "Polystyrene aggregate concrete subject to hard impact.". Proc. of the Institution of Civil Engineers, London, Vol. 89, Part 2, (pp. 225-239.). London. 1989.

[4] BS 1881: Part 116. “Method of determination of Compressive Strength of Concrete Cubes. London British Standard Institute. 1983.

[5] ISO 178: Method of determination of flexural strength test of concrete cubes. 1993.

[6] ASTM D 695 M-91:Method of determining the split tensile strength of concrete. 1988.