An Investigation into the Properties of Concrete Containing Polyethylene (Pure-water sachet waste)

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Abstract - *One of the major environmental pollution problem experienced in Nigeria results from wastes disposal. In the recent, one of these wastes like the polyethylene wastes such as pure water sachets (PWS) which is non-biodegradable is increasing as a results of increase in population. This study investigates the performance of shredded PWS waste in concrete by partially replacing fine aggregates in different percentage of 0, 0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 1.5 & 2.0% as an alternative means of disposal. A mix ratio of 1:2:4 was used and a total of 108 cubes (150mm x 150mm x 150mm) were cast, cured and tested at 7, 14 and 28 days respectively to determine its water absorption capacity, compressive strength and density of such concrete. The research thus revealed that incorporating shredded PWS in concrete has no significant effect on the water absorption property of concrete as the rate for all the samples are within acceptable limit based on standard. Increase in dose of PWS in concrete reduces the density of the concrete. The study also shows that 0.2% of shredded PWS incorporated in concrete gave a high compressive strength comparable to the control. However, this study recommends that 0.2% of SPBW incorporated in concrete can be used in concrete production since it falls within the minimum requirement for ordinary concrete with an average compressive strength of 10.0N/mm^2 as recommended by BS8110 1(1997).*

Keywords - *Polyethylene waste, PWS, Compressive Strength, Water Absorption Rate, Density*

I. INTRODUCTION

One of the rapid growing industries in the country is the plastic industry owing to a rapid increase in population. The increased population growth accounted for the generation of more plastic products to cater for the ever increasing population growth. The disposal of this generated plastic wastes has turn out to be a major challenge in the country as these materials are non-biodegradable. Wastes according to [15] are materials of solid or semi-solid matters that the processor no longer considers of sufficient value to retain. A mere look at most streets in the country is an ugly experience as the amount of waste substances which are predominantly polyethylene wastes (pure water sachet-PWS) and the likes are found as litters around the nooks and crannies of the country. Means of such waste disposal such as incineration is almost not in existence anymore probably because of its associated environmental implication among other reasons. Landfills are also filling up fast while open burning of these wastes produces greenhouse gasses [13]. Most developing countries have been making efforts towards recycling these wastes particularly the plastic wastes under which the PWS falls. However, according to[6] and [10] the disposal and recycling of waste is not commensurable to the quantity of waste being generated annually. Though, a reasonable portion of these wastes are recycled, many others post-consumer polymer wastes like water sachets, polythene sheets, bread bags, PET bottles, packing strips etc are still found all around the country as litters. In as much as plastic waste are recyclable, they still remain comparatively untouched as they are difficult to separate from other household garbage. According to [10] and [4] sachet water bags forms a very big chunk in the plastic waste materials and environmental pollution in Nigeria. The disposal of consumer generated plastic waste is a threat to the ecosystem. In other to avoid this pollution crisis, recycling and reusing of plastics has been in practice. According to [14] and [17] recycling is one of the most promising approaches to waste management of both disposable and durable product types. Reference [1] highlighted that of the millions of tonnes of garbage that are produced each year, recycling everything possible will help reduce the consumer waste production and in turn reduce disposal impact in the world.

The concrete industry all over the world is consuming billion tons of concrete every year and all the materials required to produce such huge quantities of concrete come from the earth's crust, thus reducing its resources and causing ecological strains [9]. Disposal of such solid wastes involves economic issues as well as ecological and environmental considerations. The major ecological strain in disposal of solid waste may be due to the presence of waste plastics in it [9]. Solid wastes disposal has been a major concern in Nigeria and demand urgent attention.

The Nigeria construction industry seeks to find a better and a cost effective materials (additive) to concrete in other to increase the strength. Therefore, in concrete production, any material that can complement aggregate or cement thereby reducing the production cost and having required properties will be of great interest. Alternatives to cement or sand as a material for construction are very desirable stimulants for socio-economic development of the country. Research has shown that the inclusion of mineral admixtures in construction materials has significant improvement on its strength, durability and workability [16]. In recent years, the use of Polymer materials in construction is gaining attention and expanding due to increasing demand in the construction industry. Polymers have been used as substitute or partial substitutes for cement and as effective repair material both individually and in combination with cement. The very high porosity of concrete, formation of void, capillaries, disintegration due to formation of free lime as a hydration reaction product in concretes are disadvantages severely limiting strength, durability and toughness of concrete under severe service condition. These shortcomings in Portland Lime Cement (PLC) can significantly be improved by incorporating polymer in various forms.

Reference [4] investigated the strength properties of polymer (PWS) sand aggregate concrete with a view of replacing conventional cement concrete in construction applications as a way of reducing environmental pollution with non-biodegradable PWS. Results of their study showed that the compressive strength reduced as the polymer content increased. The compressive strength result ranged from 2.0N/mm^2-0.5N/mm^2 at an average of 1.2 N/mm^2. Findings by [7] showed that the compressive strength of polyethylene mortar surpasses that of normal mortar, the density is between 1481 to 1557 Kg/m^3 which was comparable to 1585 to 1737 kg/m^3 obtained for the normal mortar. The degree of sorption of the polymer mortar was also found to have satisfied the assertion made by [18].

Owing to the fact that the use of alternative materials in construction is being encouraged, this work is thus seeking an alternative use for polyethylene wastes by its incorporation in concrete production with a view to investigate some engineering properties of such concrete while proffering alternative means to the disposal of PWS wastes which constitute disposal problems and would have turned out to be hazardous to man and his environment.

II. MATERIALS AND METHODS

A. Materials

The materials used for this study include waste polyethylene (pure water sachet), Portland Lime Cement (PLC-grade 32.5), Fine aggregates (Sand), Coarse aggregate (Granite) and water. The fine aggregate used for this study was ensured freed from dirt and other deleterious materials like sea shells. The fine aggregate used were those that passes through 4.75 mm British Standard sieve and satisfies the fine gravel limit in accordance with BS EN 933-1 (1997) while the granite grain size is between 19 – 20mm sizes. Potable water free from particles as specified in BS EN 1008 (2002) was used for the mixing. The polyethylene waste was sourced from a Pure Water sachet bags recycling company within the central business districts of Lagos. PLC used in this study was manufactured by Dangote Cement Company in Nigeria

B. Batching, Mixing and Casting of Concrete Cubes

The collected PWS was washed, air-dried and shredded mechanically into sizes ranging between 30 – 50 mm length and 15 – 35 mm width. Batching was carried out in 1:2:4 mix ratio in accordance with [5] having obtained a homogeneous dry mix manually. Shredded PWS was added in different percentages of 0.1 – 2.0% by volume to produce concrete cubes of size 150 x 150 x 150mm. However, 0.1 – 1.0% was added at 0.1% interval while 1.0 – 2.0% was added at 0.5% interval. While maintaining a water cement ratio of 0.55 the concrete cubes were cast. In this study, an attempt was made to use various proportions of waste plastics in concrete and studies were conducted to focus particularly on the behavior of such concrete elements in compression and tension. The polyethylene material used in this investigation was shredded PWS waste. The shredded PWS wastes will then be mixed with cement concrete in various proportions of 0.1% to 2% and test specimens (150x150x150mm cubes) was cast to investigate the performance of the shredded polythene waste mixed concrete by conducting compressive strength and water absorption tests.

C. Test of Hardened Concrete

The water absorption, density, and compressive strength were investigated to study the performance of concrete containing PWS.

a) Density of Concrete

The density in Kg/m^3 was computed in accordance with … using the relationship shown in Equation 1;

$$\text{Density of concrete} = \frac{mass\ of\ concrete\ in\ kg}{volume\ of\ cube\ in\ m^3} \quad (1)$$

b) Compressive strength

The test samples were weighed and placed centrally in the load frame of the semi-automatic compressive testing machine. Load was applied until the concrete cube fails and the failure load and compressive strength was computed in conformity with BS EN 12390-3 (2002) using Equation 2. The compressive strength was checked at 7, 14 and 28days of curing by total immersion in water.

$$f = \frac{F}{A} \quad (2)$$

Where f is the compressive strength (kN/m^2), F is the maximum load at failure and A is the cross-sectional area of the concrete samples on which the compression force was applied.

c) *Water Absorption Test*

The concrete (cubes) were removed from the curing tank and allowed to dry, then placed in the electronic oven to dry at 105^{0}C for 24 hours. The samples were removed from the oven and allowed to cool at room temperature then weighed to determine the initial weights before immersion in the curing medium. The final weights were determine after immersing the mortar samples in the curing medium for 24 hours then removed to cloth dried and re-weighed. The values obtained were recorded and the results were calculated to assess the rate of absorption of the concrete specimens in accordance to [3].

III. RESULT AND DISCUSSION

A. *Analysis of Water Absorption Capacity*

The water absorption capacity was found to be highest on the sample containing the least dose of PWS which is 1.51% at 0.1% content of PWS among all PWS concrete as shown in Table 1. The control sample was found to have a sorptivity of 1.06% which was found to be higher than what was obtained for 0.2 to 1.5% PWS concrete samples and lower than that of 2.0% PWS concrete. However, in this study, the least sorptivity was recorded on the sample containing 0.5% PWS at 0.48%. It can therefore be deduced from this behavior that the optimum water absorption occurred at 0.1% dose which tends to reduce as the PWS content increases up to 0.5% PWS content before progressively increasing up to 1.25% at 2.0% PWS content. This progressive increase could be as a result of over dosing the concrete with PWS which lead to creation of more pore spaces between the aggregates and allowed for passage of water. Overall, the entire specimen including the control falls between the standard specific water absorption values of ordinary concrete based on the assertion made by [18] which stated that the average absorption of test specimens shall not be greater than 5%.

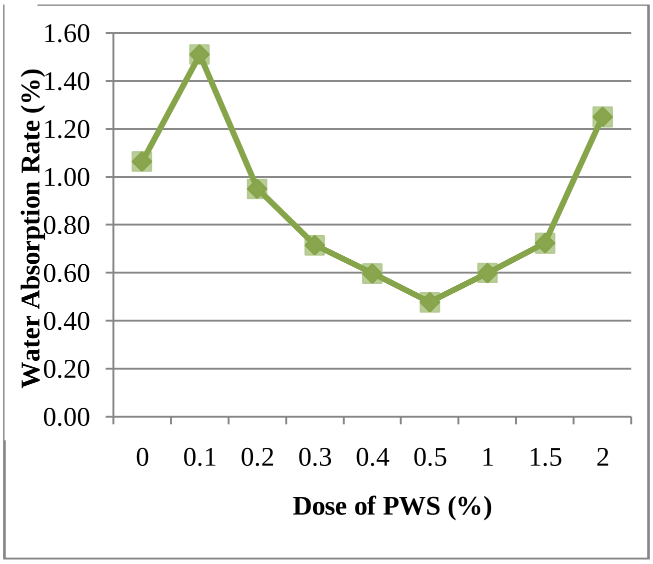

Fig. 1. Percentage water absorption rate of concrete samples

B. *Analysis of Compressive Strength*

The result obtained from the values of the compressive strength test of the various concrete samples incorporated with varying percentages of shredded polythene wastes after being cured for periods of 7days, 14days and 28days respectively is presented in Figure 2. The Figure 2 clearly shows that as the compressive strength increases with increase in curing days across all the concrete samples. However, for the control sample with 0% shredded PWS, an increase in compressive strength as the curing ages increased from 7 to 28 days amounted to about 59% strength increment as can be observed in Figure 2. Generally, there was increase in compressive strength but was highest on the concrete sample containing 0.2% shredded PWS which has 5.56 and 10.57kN/m^2 compressive strength at 7 and 28 days respectively which represents about 90% strength gain. The shredded PWS concrete containing 0.1% appears to be slightly lower in strength but comparable to the control. It can also be depicted from Figure 2 that from 0.2% concrete sample, the compressive strength begins to reduce continuously following similar trends from sample to sample except at the 1.0 and 1.5% PWS concrete samples that have a similar compressive strength**.** Overall, the control and 0.2% PWS concrete samples have their average compressive strength around 10.0kN/m^2 which satisfies the minimum requirement for a grade 10 (M10) concrete as according to BS8110 1(1997). Findings here are similar that of [7]. Therefore shredded PWS can be incorporated in concrete production at 0.2% of fine aggregate for concrete applications.

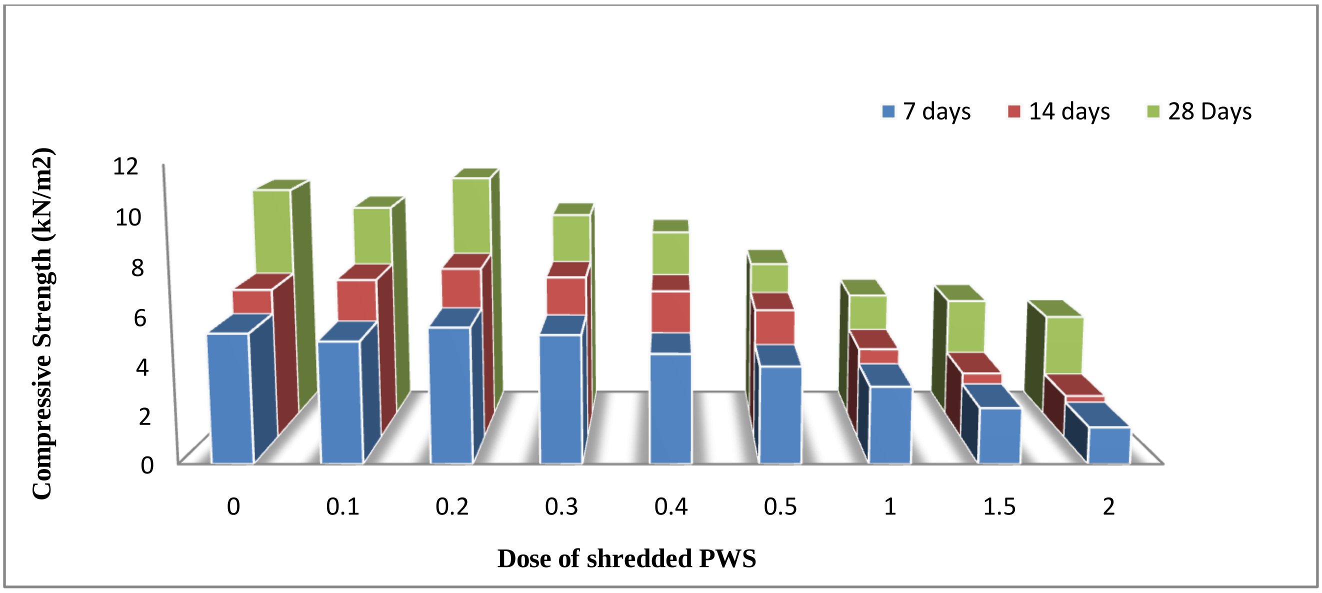

Fig. 2. Compressive Strength

C. Analysis of Density of Concrete

From Figure 3, the highest density was recorded against the concrete sample containing the minimum PWS which is 2589kg/m^3. This was followed by 2533 kg/m^3 of the control sample. A similar reduction pattern which ranged between 6 to 15kg/m^3 was observed on other PWS concrete samples as the dosage of the PWS content increases from 0.2 – 1.5%. At 2.0% PWS content, a significant drop was observed in the density of the PWS concrete which is about 74 kg/m^3. In this study, the densities of the PWS concrete samples was found to largely depend on the percentage quantity of PWS dose present in the concrete. In order words, the density reduces with increase in dosage of PWS which can simply be explained by the PWS light weight property.

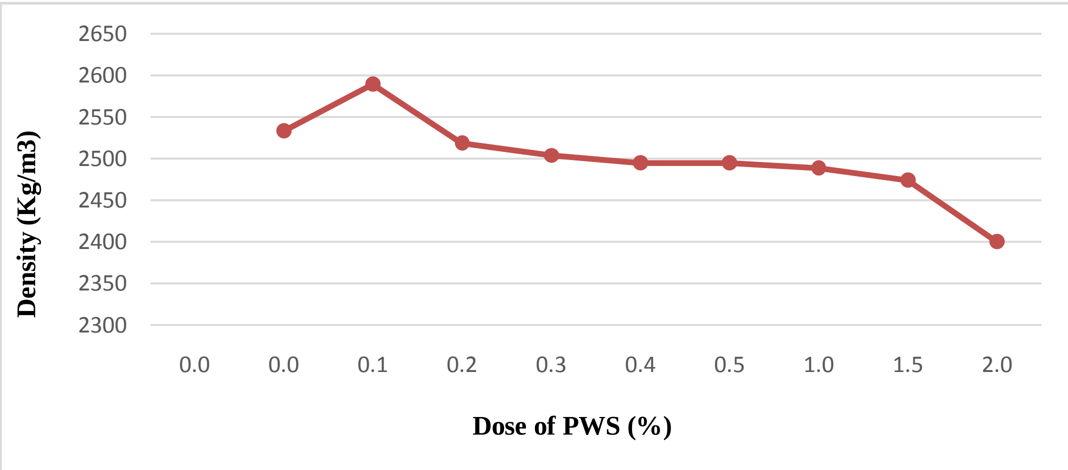

Fig. 3. Density of Control and PWS-Concrete

IV. Conclusion and Recommendation

i The study has conclusively revealed that shredded polythene waste bags can be used for the production of ordinary concrete.

ii. The use shredded polyethylene waste (PWS) in concrete reduces permeability and density of concrete.

iii. Incorporation of shredded polyethylene waste of 0.2% of fine aggregate in concrete production is recommended for concrete applications as it satisfies the minimum requirement of BS8110-1 (1997).

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