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Mechanical Properties of Concrete Produced with Waste Plastic Aggregate

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Abstract: *The menace of plastics in Nigeria has increased significantly and its recycling has become one of the major challenge. Consequently, the study selected waste Polyethylene terephthalate (PET), to probe the prospect of using it as an aggregate in concrete production. The pet bottle was melted and molded in shape of aggregate. Concrete cubes measuring 150×150×150 mm and beam samples measuring 100×100×400 mm were cast, using a mix ratio of 1:2:4 and a water/cement ratio of 0.5. The samples were tested for workability, compressive strength and flexural strength at 0% (control mix), 5%, 10%, 15% and 20% replacement of coarse aggregate (by weight) with plastic aggregate at 28days age of curing. At 5% and 10% replacement there is an observed 10% and 20% decrease in the compressive of concrete compared to the control. The minimum value of compressive strength was 19.27 N/mm2 at 20% which exceeds the minimum standard for structural application. There was an observed 8.4% and 32% decrease in flexural strength at 5% and 10% respectively. The study concludes that the plastic aggregates can be incorporated upto15% in concrete. Its use in concrete production would lead to better and profitable environmental control of industrial waste.*

Keywords: Concrete, Compressive strength, Plastic, mechanical properties, PET waste

Introduction

The demand for buildings worldwide is high as provision of shelter is key to sustaining the world's growing population. Concrete remains the best building material to meet this demand, however, in places where these materials are hauled out uncontrollably its production has led to overuse of available gravel (coarse) and sand (fine) and hence its depletion. The extraction of these materials alter the habitats of plants and animals, leads to soil erosion air and water pollution, and its processing polluted in the air which is injurious to human respiratory system[1,2]. As a result there has been an increased search for alternative materials that can replace these aggregate partially if not wholly. The creative usage of waste material signifies a way out to eliminating some of these problems and equally effective solid waste management. Plastic wastes, an industrial waste poses harmful impact on the environment as a result of their long biodegradation age [3]. Presently, the major ways to reduce these waste are incineration and recycling [4]. Despite so much energy put in to recycling of plastic research has shown that a substantial amount of plastic waste will still be left unrecycled [5] Plastic waste can be employed in concrete as the service life of concrete is longer than the plastic one, this will reduce left over un-recycled plastic and diminish its impacts on ecosystems[6]. Plastic waste in concrete will not only promote an effective disposal method but may also improve other mechanical properties of concrete. Therefore, in this study, the most common bottle plastics were collected from the landfill and environment to be incorporated in concrete as coarse aggregate with the intention of examining its contribution to improvement of concrete properties.

Literature Review

There are various types of plastic waste in circulation, but the most common type is polyethylene terephthalate (PET). Hence it is the most difficult type of plastic causing environmental menace. Consequently, several studies have been carried out towards its reuse and thus environmentally friendly by incorporating it in concrete production. The studies include its use as fine and coarse aggregate, and as fibre in concrete. [15] uses high density polyethylene (HDPE) to test the structural qualities of concrete in which fine particles have been replaced with granulated plastic waste (GPW). The results demonstrated that a broad range of high early strength was attained with compressive strengths of 21.42N/mm2, 17N/mm2, and 9.67N/mm2 for 10%, 20%, and 30% replacement of fine aggregate, respectively, while the control is 21.75N/mm2 at 28days test. For structural work, a 10% replacement is advised; for non-structural work, such as solid ground floors and light weight concrete, 20% and 30% replacements are advised. In a research carried out by [7] pulverized plastics and glass were used as partial replacement of sand up to 20% concrete mixes, and crushed concrete used as

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replacement of granite. The results of slump and compressive strength test showed a decrease of 25% and 72%, respectively. [8] Concluded through their study on mechanical properties of concrete using plastic waste as an aggregate that at all curing ages the compressive strength decrease as a result of poor adhesion between the plastic waste and cement paste. Similarly, the conclusions of the research carried out by [9,10,11] shows that addition of plastic to concrete causes reduction in concrete properties. There was equally an observed decreases in modulus of elasticity of concrete as compared to traditional concrete [11]. In an investigation carried out by [12], it was found that the use of plastic waste in a concrete as fiber results in an increase in the mechanical properties of concrete. This similar trend was observed by [13] when PET waste was incorporated as a fiber in concrete in varying percentages. This is contrary to research carried out by [14] which showed that incorporating PET fibers in concrete led to a decline in the compressive strength and elastic modulus. This was affirmed in a similar research carried out [15] that revealed that adding PET fibers causes a reduction in the mechanical properties of concrete. Hence the need to probe further into the behavior of concrete when PET are used as replacement of aggregates.

Material and Methodology

The research requires obtaining concrete materials such as Sharp sand, Granite, cement and Plastic. PET bottle used were all gotten from the premises of the Federal Polytechnic Ilaro, Ogun state. The pet were retrieved from waste dump site at different locations in the east and west campus. The plastic bottles were melted in an air tight container and the molten plastic in its fluid state was poured into a metallic mold that gives it a cubic shape of an average size of 19mm. The molded plastic was coated with sand to give the plastic a rough nature with the intention to enhance the bonding capacity of aggregate. Both the coarse and fine aggregates underwent sieve analysis. A uniform set of sieves was used to let 200g of each sample pass through. Weighing the aggregate that had been retained on each sieve. Calculations and a graph of the % passing in relation to sieve size were made.

Figure 1: Plastic aggregate

Casting, Curing and Crushing

The mix proportioning was done using the volume batching technique. The mix ratio [1:2:4] was used to calculate the necessary amount of ingredients. A water cement ratio of 0.5was used for good workability of concrete. These were determined by the slump test which was carried out according to British Standard [16].

A standard 150×150×150mm cube specimens, 150mm×300mm and 100×100×400mm beam were cast at 5%, 10% and 15% and 20% by volume in replacement of coarse aggregate. For every percentage replacement of plastic aggregate a total 3cubes were cast. The samples were demolded after 24 hours of casting and placed in water curing tank for subsequent days to be weighed, dried, and crushed to test for the compressive strength, water absorption and flexural strength at 7, 14 and 28days age of curing.

Result and Discussion

Sieve Analysis

The granite and plastic aggregates used had similar size fractions of 19mm. All the aggregate Sieving for the aggregates particle size distributions were in accordance with BS1377-2. The mechanical properties of aggregates are shown in table 1.

Table 1: Mechanical Properties of Aggregate

	Plastic aggregate	Granite	Sand
Specific gravity	0.89	2.75	1.82
Aggregate Impact value	24.9	29.9	-
Fineness Modulus	-	4.973	3.214
Aggregate Crushing value	7.9	25.8	-

Density of Concrete

This examines the effect of replacement of granite with plastic aggregate on the weight of concrete. For all percentage replacement of granite with plastic aggregate there was a decrease in the density of the concrete samples (Figure 2). Concrete sample with 5% plastic aggregate have a value of 2160kg/m3 at 28days compared to 2240kg/m3 (control).

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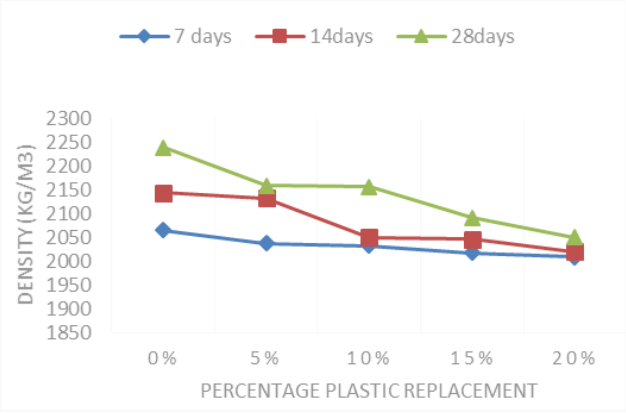


Figure 2: Average density of concrete

Water Absorption

The water absorption capacity of the concrete at all ages of curing is shown in Figure 3. It decreases with increase in the level of application of plastic aggregate. The result revealed that utmost probable performance of the plastic aggregate is workable at 5% application.

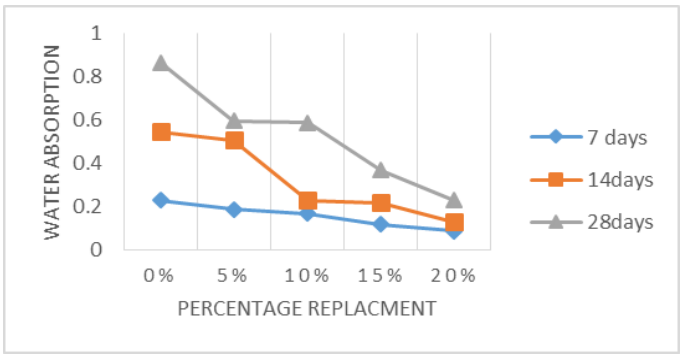
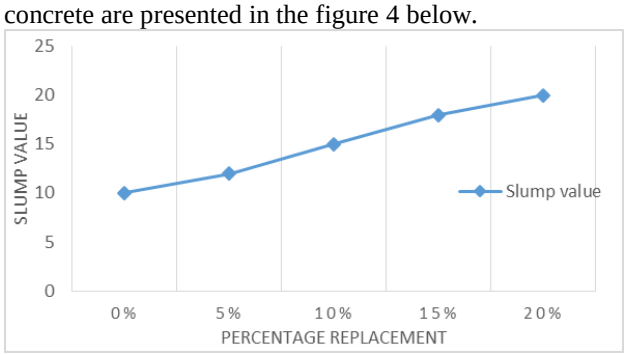


Figure 3: Water absorption of concrete

Workability Test

Slump was measured according to BS EN 12350-2. The values obtained from testing the workability of fresh concrete are presented in the figure 4 below.



The slump value of concrete was found to increase with increase in amount of plastic aggregate replaced in concrete (figure 4). This is as a result of the nature of the aggregate surface. This is mainly ascribed to the lower water absorption by the plastic aggregate compared to that of granite which increases the free water.

Compressive Strength

The compressive strength reduces with increase in percentage of 5%, 10%, 15% and 20% but the strengths is adequate for a light weight concrete. Compared to previous researches, the strength decreases as a result of weak cohesion between the plastic aggregate and cement paste. This is as a result of the surface nature of the aggregate. Figure 5 shows that at 5% replacement there is an observed 10% decrease in the compressive of concrete compared to the control. At 10% replacement, there is an observed 16% reduction in concrete strength and on further replacement strength was found to be decreasing till 20% replacement of natural aggregate with plastic aggregate which resulted in 22% reduction in compressive strength on concrete.

Plate2: Compressive strength test

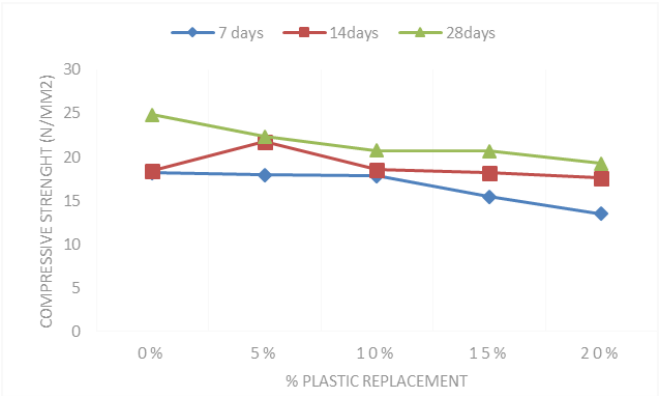


Figure 5: Compressive strength of concrete

Flexural Strength of Concrete

After 28 days of standard curing the beam were tested for flexure. There was an observed decrease in flexural strength of concrete produced at all levels of replacement with reference to control as shown in figure 6. Variation of flexural strength as it decreases is however not too

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significant. This is evident as there was an observed 8.4% and 32% decrease in strength at 5% and 10% respectively.

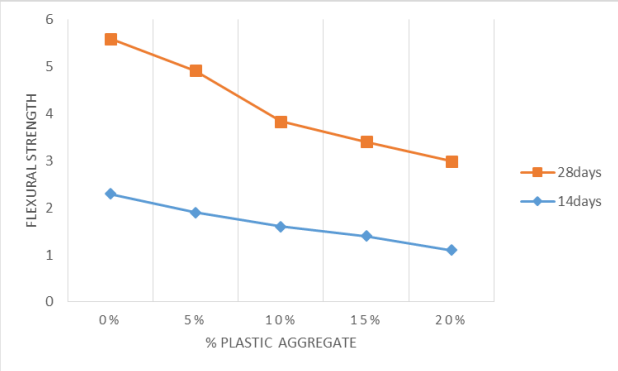

Figure 6: Concrete flexural strength

Conclusion and Future works

At 5% replacement there is an observed 10% decrease in the compressive of concrete compared to the control. At 10% replacement, there is an observed 16% reduction in concrete strength and on further replacement strength was found to be decreasing till 20% replacement of natural aggregate with plastic aggregate which resulted in 22% reduction in compressive strength on concrete. It was equally found that the flexural strength of concrete decreases with increase in percentage replacement of aggregate. There was an observed 8.4% and 32% decrease in strength at 5% and 10% respectively. Finally, it can be concluded that the PET plastic aggregates may be used up to 10% replacement of coarse aggregates in concrete. Its application in concrete production promotes an alternative way of eliminating the waste from the environment.

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