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The Use of Plastic Waste as Transition Materials in the Production of Pavement Block

Anand Sarvankar, Tushar Varose, Mohit Vaze
Email :anand040999@gmail.com
tvarose@gmail.com
mohitvaze1998@gmail.com

Abstract—*Due to globalization many developing countries faces lot of challenge of waste. The plastic waste which is part of solid waste poses a menace to sustainable development due to its slow rate of degradability and the indiscriminate way it is disposed. To lessen the negative impacts on the environment and the associated effects on human health, plastic waste is being considered as materials in transition and are being used in the production of pavement blocks and other materials for construction purposes. The study reports some physical and mechanical properties of plastic waste pavement blocks produced by one company in Ghana which has taken a major lead in the direction of adding value to plastic waste for construction. Results are compared to two other pavement block types made from cement and fired clay pavement blocks and discussed. Using plastic waste as transition materials for pavement blocks may among other benefits listed, translate to reduction in construction cost and large quantities of plastic waste polluting the environment and may contribute to cleaner cities and towns.*

Keywords—construction, environment, Plastic waste; Pavement blocks, transition materials

I. INTRODUCTION

Economic growth and changing pattern resulting in rapid increase in the use of plastics in the world. Thus, consumption of plastic material has increased from 5 million tons in the 1950s to 100 million in the 2000s. In Ghana per capita generation of plastic waste has been reported to be between 0.0016- 0.035kg/person/day. And, plastics make up between 18-20% component materials in the waste stream [1]. There are however concerns about plastic waste disposal methods commonly employed in many developing countries as they do not deal effectively with the large tonnes of plastic waste generated. These disposal methods include dumping plastic waste in landfills, incineration and open littering. Since plastics take several years to degrade, there are challenges associated with their improper disposal which include:

i. Blocking drains and choking of gutters which may contribute to floods.

ii. Release of toxic gases into the atmosphere when openly burnt. Some of these gases may be harmful to humans and cause greenhouse effects.

iii. Discarded bottles and containers may serve as breeding grounds for mosquitoes when filled with rainwater.

iv. Washing of the littered plastic materials into water bodies including oceans contributing to decline of ocean life.

Common pavement materials used in Ghana include the cement pavement blocks and the fired clay pavement bricks. Portland cement imported into the country is used in the production of cement pavement blocks and is associated with increasingly high cost due the unstable value of foreign exchange. Fired clay pavers produced from available local clay materials are not very popular with a lot of people because they are perceived by many as expensive. The production of fired clay pavers currently in the country relies on firewood burnt at very high temperatures. This firing method is not sustainable and associated with consumption of a lot energy. In recent times, due to the ecological and environmental challenges associated with the disposal of plastic waste, there are a lot of interest in turning plastic waste into a resource in construction. Pavement blocks produced from waste plastic and other materials like sand, quarry dust etc., is recently being promoted in many developing countries as a more affordable and a sustainable material which may be used in construction and Ghana is no exception. Though it is generally known that these plastic waste pavement blocks are strong and durable, there is little scientific data in Ghana to support this claim. This paper therefore reports a study on three types of pavement blocks produced from plastic waste, fired clay and cement.

II. MATERIAL

The pavements samples under study were obtained from three different commercial paving factories in Ghana. The raw materials used in the production of these pavers comprised of cement, quarry dust and fine aggregates (sand), for the cement pavers, clay for the clay pavers, and waste plastics and sand for the plastic pavers. Six samples of each paver types were randomly selected and tested for each of the various physical and mechanical properties which include density, compressive strength, flexural strength, abrasive resistance, water of absorption and durability in sea water. Plastic pavement blocks were commercially produced in bigger sizes of 30cm by 30cm. They were cut into 4 equal part with half remaining. And test run on samples of dimension 20cm by 10cm with a thickness of 5cm. This is to make sure all types of pavement blocks have comparable sizes. Cement and fired clay pavement blocks are of hexagonal shape and with dimensions 23cm by 14cm with thickness 5m and 20m by 10.5 with thickness 6.5cm respectively. The samples were cured for more than 28 days to ensure maximum mechanical strength development before the various test were conducted.

III. METHODS

1.Density:

The density of the various paving bricks was determined using Archimedes principle of water displacement. Dry weights of various pavers were measured and fully immersed in a tank containing water. The volume of water displaced was measured for each pavement type, and the average volume of water displaced was recorded for six samples each of the various pavers. The densities of the various pavers were determined by dividing the dry weight by the volume of water displaced [2**].**

2. Compressive strength:

The compressive strength is the most prioritized property to be achieved in the production of paving bricks in almost every factory that is actively involved in manufacturing of pavers [3]. Hydraulic universal testing machine which has a maximum capacity up to 2500KN was used to determine the compressive of the various pavers in this study. The load was applied to the nominal area of the cement, clay and rubberized pavers to determine the various compressive strengths. The corrected compressive strength was computed using correcting factors (BIS, 2006).

3.Flexural strength

Flexural strength is one of the tests performed on paver blocks which serves as a quality indicator and it is considered as a basis for comparison in terms of wearing resistance. Flexural strength test was performed by subjecting the various pavers to a that wise force which is perpendicular to its longitudinal axis. A center line was indicated on top of the pavers which is perpendicular to its length. The pavers were supported by two support rods over a span of 150mm and were tested under a central line load until failure occurred, using the INSTRON universal testing machine. The flexural strength values recorded are the average of six samples each for the various paver [4].

4.Water of absorption and durability in sea water

Water of absorption is the determination of the rate of absorption by measuring the increase in mass of the pavers resulting from absorption of water over a period. The pavers were fully immersed in a tank of fresh water for 24 hours and the weight measured to determine the percentage of water absorption. And, the pavements were fully immersed in a tank of sea water for four months to determine its durability by applying a load to determine the compressive strength using the universal testing machine.

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The percent water of absorption is determined using equation (1),

% water of absorption = ((wet weight – dry weight)/dry weight) × 100 (1).

IV. RESULTS

1.Density

The density values of the various pavers are presented in Figure 1. The values range between 1.99g/cm3 to 2.04 g/cm3, with fired clay pavement block having the lowest and cement pavement block having the highest.

Figure 1: Average density of the three different pavers.

2.Compressive Strength

As shown in Figure 2 , fired clay pavement block recorded the highest compressive strength followed by the plastic pavement blocks with the cement pavement blocks recording the least compressive strength.tests were carried out using different kind of plastics with varying percentages of substitution. Decline in compressive strength was observed with increase in percentage of plastic. Among the different kinds of plastics tested , the highest strength was obtained with polythene bags. This may be attributed to the fibrous nature of the material.

Figure 2: Average Compressive strength of the three different pavers.

3.Flexural Strength

the test results of flexural strength of plastic paver, cement paver and fired clay paver to be 6.04MPa, 5.86MPa and 5.09MPa respectively. Flexural strength up to 75% is achieved for a mix of PCA up to 15%. Flexural strength up to 52% is achieved for a mix of PCA up to 30%. The reduction in strength of plastic replaced concrete is due to deficient bonding of plastic aggregate in the matrix.

4.Water of Absorption

the percentage water of absorption test results for fired clay, cement and plastic pavers as 11.82, 8.075 and 0.369 respectively. It was absorbed that percentage of water absorption was increased with the addition of plastic aggregates. For concrete specimen containing 20% volume of plastic, water absorption was higher than that of the specimen without plastic aggregate. When substituting part of the natural fine aggregates by PET ,The latter creates a proper and different porosity to that one created by the sand since its shape is plane and elongated.

5.Abrasion Resistance

Abrasive resistance is a measure of the resistance of paving brick to the wearing action due to traffic and can be calculated using equation (2).

Abrasive index = (water absorption/ compressive strength)*100 (2)

The maximum abrasion index for Type III i.e. pedestrian and light traffic pavement is 0.50 and the minimum abrasion limit for a 28day cured concrete paver is 1.20 for footpaths and car parks (ASTM C 902-15). The three types of pavers have abrasion index of 0.35, 0.14 and 0.014 for clay, cement and fired clay pavement blocks

V. DISCUSSION

The density of fired clay pavers has been stated to be between 1.826g/cm3 and 1.985g/cm3, and specific gravity of special masonry varies between 1.20g/cm3 and 2.40g/cm3(ASTM C-902). From the results in Figure 1, Clay pavers had the minimum density value followed by the plastic and cement pavers of densities 2.04g/cm3 and 2.10g/cm3 respectively. The 3 types however fall within the standard specification. Clay pavement blocks recorded higher average compressive strength, followed by plastic pavement blocks and then cement pavement blocks. Clay pavement blocks have highest thickness compared to plastic and cement pavement blocks and this may have contributed to the high compressive strength. Also, the compressive strength of the plastic pavement blocks was not determined on full blocks but on a cut-out section, may have caused a reduction in the compressive strength of plastic pavement blocks as noted by Vila et al. [5]. The production of fired clay pavement blocks currently in Ghana relies on firewood and requires much energy during firing. Harmful gases such CO2 may also be released into the environment which is not eco-friendly. When firing is not well controlled, clay bricks can develop cracks which may lead to reduction in strength. Cement pavers recorded the least compressive strength value as compared to the plastic pavers. Poor compaction is a major factor that influence the strength of cement pavers which creates more pores to absorb water. Secondly, decreased strength in concrete pavers can be attributed to variation in the mix proportions in the batching process.

VI. CONCLUSION

In this study clay pavement and plastic pavement blocks obtained higher average compressive strength than the cement pavement blocks. Durability studies suggested that plastic pavement blocks may perform better in areas prone to flooding and high saline content. Though the various pavement blocks may be used for footpath, light traffic, walkway etc., the plastic pavement blocks made from waste plastic and sand may be cheaper and represent an alternative way of turning waste material into useful product for a more sustained construction. Plastic waste use as transitional material in construction is a demonstration of how waste could be turned into a resource for cost effective, yet a durable and sustainable material for construction. Other advantages include minimizing plastic waste in the environment, the landfills and water bodies contributing to cleaner cities and towns and creation of more jobs.

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