# Production of Pavement Blocks from Plastic Waste

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## ABSTRACT

The need for the construction sector to be sustained by innovative technology targeted at conserving the natural resources and protecting the environment cannot be overemphasized. The use of plastic wastes as additives in the production of pavement blocks has both engineering and environmental implications. The use of paver blocks produced from plastic wastes is becoming more popular, finding applications in parking areas, compounds, open spaces, streets, and in minor and major roads.

The way and manner plastic wastes generated are managed in developing countries is worrisome and disturbing, due to their non-biodegradable nature. The research is aimed at using plastic wastes as binding groundmass in place of cement in the production of pavement blocks. This will go a long way in solving part of our environmental and ecological problems resulting from indiscriminate dumping of plastic wastes. Plastic wastes (LDPE type) were melted at temperatures between 180˚C-250˚C in a closed system and mixed in different proportions (70:30, 60:40 and 50:50) with granite-dust, sand and clay to produce sample paver blocks. The same mold was also used to produce cement paver blocks.

These blocks were subjected to flexural, compressive-strength, water-absorption, oven and acid tests. The results of these tests revealed that paver blocks produced from plastic additives show more tensile strength, better water absorption, more resistant to corrosion and good heat absorber compared to the blocks produced from cement. Plastic paver blocks also showed abysmally low water absorption than the cement blocks.

The application of plastic waste in the production of paver block is an innovative way of disposing plastic waste littered all over the place, thereby cleaning the environment. The cost of plastic waste paver block when compared with concrete paver block is stronger, tougher, economical and more resistant to heat and corrosion. The study has clearly established that plastic paver blocks are better alternative to normal cement paver blocks.

(Keywords: pavement blocks, geomaterials, engineering properties, Lagos, Nigria).

## INTRODUCTION

Pavement blocks produced from ordinary cement in Nigeria has performed very well except failures resulting from excessive surface wear (abrasion), and variability in their strength as well as growth of weeds/algae within the interlock space [1]. Natural resources such as limestone used in the manufacture of cement are constantly being depleted globally while generation of wastes especially plastic is on the increase on a daily basis thereby creating an imbalance in the sustainability of our dear environment. The construction sector is therefore in need of non-conventional and innovative materials, whose availability is not a challenge in order to replace the diminishing of natural resources [2-3].

Interlocking pavements are special dry mix precast pieces of concrete commonly used in exterior landscaping pavement applications. The strength, durability and aesthetically pleasing surfaces have made paving blocks attractive for many commercial, municipal and industrial applications such as parking areas for both residential and commercial, pedestrian walks, major and minor roads, [4]. It is socially attractive and economically, a better alternative to both flexible and rigid pavements made from cement in recent times [5].

Paver block is versatile, aesthetically attractive, functional, and cost effective and requires little or no maintenance if correctly manufactured and laid [6]. The causes of road failure in Nigeria as identified by many researchers include poor construction materials, poor design and specification, road usage, use of non-professionals, poor drainage, geological and geotechnical factors [7-8].

The nearness of the saturated zone to the land surface and the manner of fluctuation of this zone has direct effect on the geotechnical properties of the soil. These in turn influence the stability of engineering structures such as houses, bridges, dams, and roads [9-10].

Permeable interlocking concrete pavements are the best option for effective storm water management and surface/subsurface drainage interactions. Pore water under pressure beneath road pavements on marshy sites rises through capillary action to the surface above the groundwater level and can adversely affect road pavement structure if there is inadequate subsurface drainage facility [11-12].

The use of plastic materials has increased from 5 million tons in the 1950s to 100 million tons in the 2000s. The challenge of waste disposal has become one of the most serious environmental problems facing many cities in Nigeria [13-14]. High-density polyethylene (HDPE), low-density polyethylene (LDPE), and polyethylene (PE) are non-biodegradable plastic and they constitute a threat to the environment.

Plastics are categorized into Thermoplastics and thermoset Plastics. Thermoplastics can be heated up to form products and their end products re-heated to form other plastics while thermoset plastics once melted, cannot be re-molded into other shapes after they have solidified [15]. They stay solid and, unlike thermoplastics cannot be re-melted. Based on the advantages of thermoplastics over thermoset Plastics, it is preferably used in production of paver blocks [16-17].

Despite the huge prospects, two areas of concern are occasional failure due to excessive surface wear, and variation in the strength of the blocks. In the face of depleting natural resources worldwide, generation of plastic wastes from industrial and residential areas is on a steady increase [18]. Sustainable development (being a core mandate of environmentalists) involves the use of non-conventional and innovative materials, and recycling of waste materials in order to compensate the lack of infinite reserve of mineral resources as well as management of waste [19-20].

The economic growth, geometric population growth, and changing pattern of consumption are resulting in the rapid increase in the use of plastics in the world. Plastic wastes pose a greater management challenge because of its non-biodegradability [21]. They are corrosion resistant, have long life, maintenance free and light weighted. All these attributes that makes its waste management difficult could however be exploited to replace cement as the binding material for aggregates in the production of paver blocks [22-23].

Recycling technology has been a solution of choice in the developed countries. Many developing countries including Nigeria are currently experiencing rapid urbanization and industrialization and as a result a lot of infrastructural developments could tap into turning their environmental problem (abundance of plastic waste) into a source of cheaper and durable construction materials.

The present study is aimed at replacing cement with plastic waste in the production of paver block thereby reducing the cost of paver block and enhancing its durability. This research will therefore harness the vastly available plastic wastes all over the place which has caused environmental degradation to constructional and economical purposes, thereby turning wastes into wealth as well as creating employment.

## Study Area Description

Lagos State (Figure 1), the economic hub of Nigeria was chosen as the case study because of the huge population, presence of many industries and the large amount of plastic waste generated per day. The sharp sand, clay and plastic wastes were sources in Lagos.

**Figure 1:** Map of Lagos State (Study Area).

Geologically, Lagos consists of sedimentary formations belonging to the tertiary and quaternary sediments. Tertiary sediments are unconsolidated sandstones, grits with mudstone band and sand with layers of clay (Figure 2).

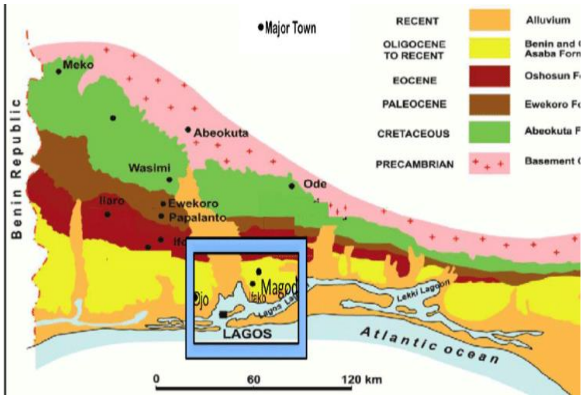

**Figure 2:** Geology Map Southwestern Nigeria showing the Study Area (Lagos State).

The granite dust was sourced from Offa in Kwara State (Figure 3) because of its non-availability in Lagos State due to the local geology [24-25].

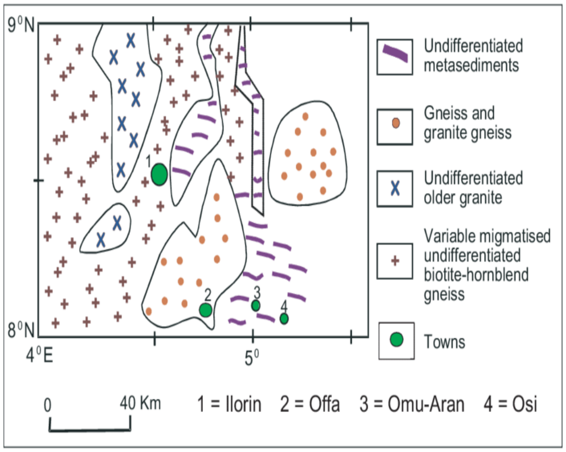

**Figure 3:** Geology Map of Parts of Kwara State Showing Offa (where granite dust was sourced).

## MATERIALS

### Cement

Ordinary Portland cement was obtained from the open market designated as CEM I in the present Nigeria Industrial Standard for cement NIS 444-1:2003 (cement with 95% to 100% blinker and gypsum, and 0%-5% minor additional constituent).

### Sand

Natural river-bed sand was collected and used. Clean and sharp sand was collected from Lagos State. It has a specific gravity of 2.65 and fitness modulus 0.4. It was oven dried at the Civil Engineering Department of the Federal Polytechnic, Offa.

### Granite dust

Granite dust was collected from local stone crushing unit from Offa, Kwara state (Figure 3). It was dry at the point of collection and was sieved by IS: 4.75mm sieve at the Civil Engineering Department, Federal Polytechnic, Offa. It has specific gravity of 2.57, fitness modulus of 2.41, density of 1.85gm/cc and void ratio of 0.42

### Clay

Clay was collected from a hand dug well in Lagos and it has a specific gravity of 2.7. The clay was sun-dried and pounded (to loosen the particles) to a fine powder.

### Plastic Materials

The plastic materials (PET, HDPE and LDPE) were sourced from Lagos State. They were washed and then shredded into very small pieces by a grinder at a plastic processing outlet.

Other materials used are hand gloves, nose masks, safety boots, 1 melting barrel, a spade with a metal shaft for staring of hot mix, Industrial gas as source of heat, mold (200mm x 100mm x 75mm), used engine oil for lubrication, metal table for mold placement, hand trowel, and a Pyrometer.

## METHODS

All the pavement block samples produced for this research work were molded from a metal mold measuring 200mmx100mmx75mm. 80 Pavement block samples were produced for each of the different mix ratios. Clean shredded plastic waste materials were melted at a temperature of about 180-250˚C and mixed in different proportions by volume.

### Plastic Melt and Granite Dust

Pavement blocks were produced by mixing plastic melt and granite dust in three different proportions by volume in ratios of 50:50, 40:60 and 30:70.

### Plastic Melt and Sand Mix Ratio

Production of pavement blocks by mixing plastic melt and sand in three different proportions by volume in ratios of 50:50, 40:60 and 30:70.

### Plastic Melt and Clay Mix Ratio

Production of pavement blocks by mixing plastic melt and clay in three different proportions by volume in ratios of 50:50, 40:60 and 30:70.

### Cement and Aggregates Mix Ratio

The materials (cement, sand and granite dust in the ratio 1:2:4 respectively) were mixed thoroughly with a shovel until a uniform mix was obtained.

-Water was added in a ratio not exceeding 0.6 to cement.
-The resultant mix was hardened and cured

### Laboratory Tests

Five tests were conducted for the study namely; Compression test, Water absorption test, Flexural test, corrosion and Oven test. Comparison was made based on all except the oven test which was undertaken to determine the temperature at which the products would fail.

### Compressive Strength Test

The Universal Testing Machine was used to measure the load that crushes each sample. The compressive strength was calculated using the following formula:

Compressive strength=Load/Area;

where the surface area for each sample is 200mm×100mm =20,000mm$^2$

### Water Absorption Test

The weight of each oven dried sample was measured as weight dry - The weight of each sample soaked for 24hours was measured as weight $_{\text{wet}}$.

The water absorption rate was calculated using the following Formula water absorption rate = (weight $_{\text{wet}}$ - weight $_{\text{dry}}$)/weight $_{\text{dry}}$ ×100%

### Flexural Test

The flexural test was carried out using an automatic Universal Testing Machine. By this test, the amount of force at breaking point of each sample was determined.

## Oven Test

The oven test was carried out by placing plastic derived paver blocks in the oven and recording the points at which they fail.

## Acid Test

Block samples were digested with a weak sulfuric acid ($H_2SO_4$) with pH value of 6. Both compressive and flexural tests were carried out on the block samples after 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 days. These test results were compared to results obtained before activation with acid.

## Data Analysis

The mean values of three specimens of every sample were taken at every instance to represent the sample for each test carried out and presented in tables. Simple Bar graphs were used to present the data from each test.

## RESULTS AND DISCUSSION

## Compressive Strength Test

Table 1 shows the result for the compressive strength of the different samples represented on the bar graph in Figure 4.

**Table 1:** Table showing the Compressive Strength of each of the 10 Sample Paver Blocks.

| Samples | Load (N) | Compressive Strength (N/mm$^2$) |
|---|---|---|
| 50% Granite dust | 300,000 | 15.00 |
| 60% Granite dust | 256,000 | 12.80 |
| 70% Granite dust | 154,000 | 7.70 |
| 50% Sand | 251,000 | 12.55 |
| 60% Sand | 180,000 | 9.00 |
| 70% Sand | 110,000 | 7.50 |
| 50% Clay | 198,000 | 9.90 |
| 60% Clay | 118,000 | 8.60 |
| 70% Clay | 168,000 | 8.40 |
| Cement/Concrete mix | 118,000 | 5.90 |

The Compression test shows that the mix ratio 50:50 (plastic melt: granite dust) has the highest compressive strength of 15.0N/mm$^2$ (Figure 4), a value which is almost three times the 5.9 N/mm$^2$ value of the cement derived pavement block, while other mix ratios equally have their degrees of variation.

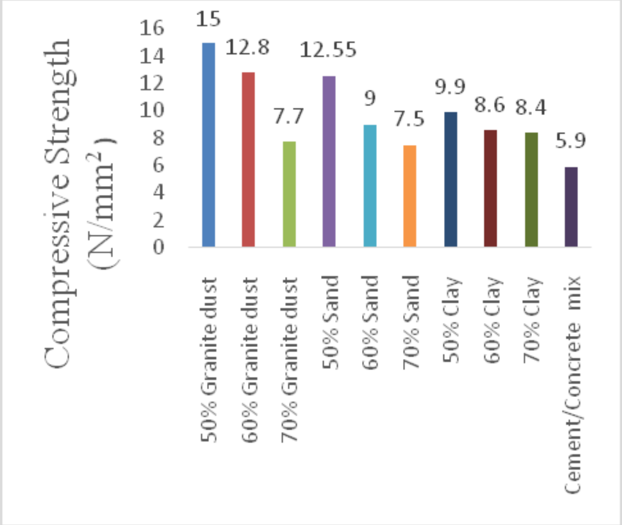

**Figure 4:** Bar Chart of Pavement Blocks at different Ratio versus their Respective Compressive Strength.

## Water Absorption Test

Table 2 shows the result of the water absorption test of the samples.

**Table 2:** Table showing the Water Absorption Rate (%) of each of the 10 Sample Paver Blocks.

| Samples | Water Absorption Rate (%) |
|---|---|
| 50% Granite Dust | 1.59 |
| 60% Granite Dust | 1.68 |
| 70% Granite Dust | 1.71 |
| 50% Sand | 1.70 |
| 60% Sand | 1.81 |
| 70% Sand | 1.83 |
| 50% Clay | 1.76 |
| 60% Clay | 1.84 |
| 70% Clay | 2.01 |
| Concrete Mix | 17.33 |

All the sample blocks produced from plastic melts have water absorption (WAR) values ranging from between 1.59% to 2.01% (Figure 5). All these values are abysmally lower than the WAR 17.33% value of the cement pavement block. This means disintegration of the cement pavement blocks by alternate wetting and drying is more likely than in the plastic derived pavement blocks. It also means underscores the reason why cement paver blocks support the growth of algae, spirogyra and mosses on its surface [26-27].

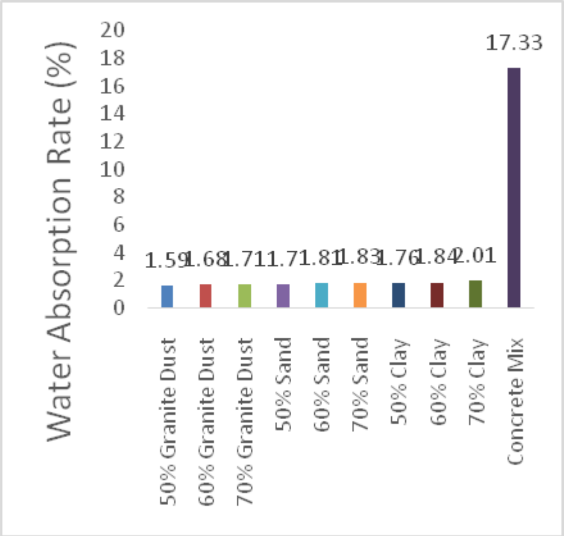

**Figure 5:** Bar Water Absorption Rate of Pavers from varying Ratio of Plastic Melts/Geological Materials and Cement.

There is also the likelihood of the surface of the blocks supporting the growth of algae and spirogyra thereby reducing its strength and aesthetic value [30]. The lower WAR recorded by the plastic derived pavement blocks give them an edge in terms of efficiency and durability especially in waterlogged areas.

## Flexural Test

Table 3 shows the result of the flexural test of the samples. It is apt to note that while forces at breaking point reduce with increasing granite dust and clay, the reverse is the case for sand (Figure 6). This could be attributed to the fact that sand is predominantly quartz rich as compared to granite and clay and as such would require a greater amount of force to break the block than when increasing mica and feldspar rich materials [28-29].

The Flexural test result shows that the mix ratio 70:30 (sand: plastic melt) has the highest flexural strength of 14.28 kN, a value which is above seven times the 1.98 kN value of the cement pavement block.

The comparisons above show clearly that all the mix ratios of plastic derived pavement blocks could withstand greater forces (aggression) before breaking than the cement derived pavement blocks.

**Table 3:** Table Showing the Force at Breaking Points (N) of each of the 10 Sample Paver Blocks.

| Samples | Force at Breaking point (N) |
|---|---|
| 50% Granite Dust | 12,640 |
| 60% Granite Dust | 10,400 |
| 70% Granite Dust | 8,360 |
| 50% Sand | 9,470 |
| 60% Sand | 10,085 |
| 70% Sand | 14,280 |
| 50% Clay | 8,690 |
| 60% Clay | 6,072 |
| 70% Clay | 4,480 |
| Concrete Mix | 1,980 |

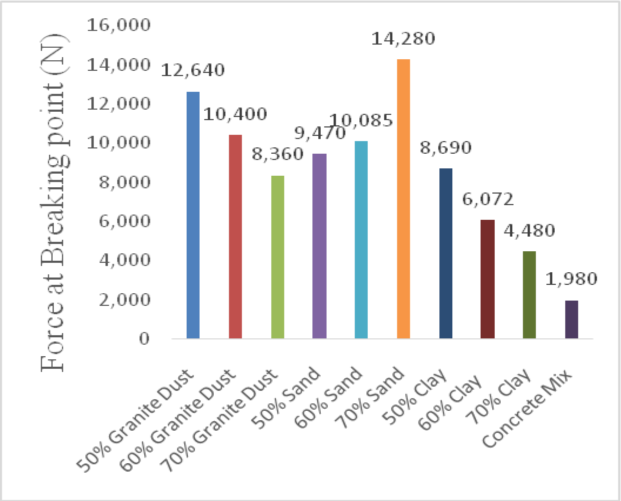

**Figure 6:** Bar Chart of Breaking Points of Geomaterials at Different Ratios.

## Oven Test

Table 4 shows the result of the over test of the samples. The oven test was carried out to ascertain the temperature at which each pavement block fails. The results obtained from the oven test shows that there was no visible change in the shape, size and rigidity of all the plastic derived pavement blocks at a temperature below 180˚C.

**Table 4:** Compressive Temperature Falling Point for Plastic Paver Block (˚C).

| Samples | Temperature of Failure (˚C) |
|---|---|
| 50% Granite Dust | 180.00 |
| 60% Granite Dust | 185.00 |
| 70% Granite Dust | 185.00 |
| 50% Sand | 180.00 |
| 60% Sand | 185.00 |
| 70% Sand | 185.00 |
| 50% Clay | 200.00 |
| 60% Clay | 205.00 |
| 70% Clay | 210.00 |

## CONCLUSION

The present study has efficiently and effectively demonstrated the application of waste plastic into useful constructional materials as well as reducing its menace in our surrounding. The plastic wastes littered all over the environment can be converted to useful constructional materials more economical than cement.

Based on the outcome of the results of the various tests carried out, the study has clearly established that the plastic derived paver blocks are more rugged, tougher, durable, heat-, and corrosion-resistant compared to the paver blocks produced from conventional cement.

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