

## COMPARATIVE STUDY ON THE ENGINEERING PROPERTIES OF PAVEMENT BLOCKS PRODUCED FROM PLASTIC WASTES AND CEMENT IN LAGOS, SOUTHWESTERN NIGERIA

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### **Abstract**

The use of plastic wastes materials in the production of plastic pavement blocks has both engineering and environmental implications. The use of plastic paver blocks is becoming more popular, finding application in paving approaches, parking area, compounds, open spaces, streets, 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 mould 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 the tests revealed that plastic paver blocks are 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. Based on these findings, the study has established that plastic paver blocks are tougher, economical, long-lasting and sustainable alternative to cement blocks. It also aid in taking plastic wastes out of our streets thereby promoting a cleaner and healthier environment.

*Keyword: Pavement Blocks, Geomaterials, Engineering Properties, Lagos, Nigeria*

### **Introduction**

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, pedestrian walks, traffic inter-sections, container yards and roads (Allaheverdi and Frantisek, 2000; Nivetha and Ankit, 2016; Huda and Hanzar, 2016).

It is an attractive engineering and economical alternative to both flexible and rigid pavements in recent times. Paver block is versatile, aesthetically attractive, functional, and cost effective and requires little or no maintenance if correctly manufactured and laid. 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 (Mohan *et al.*, 2018; Lenkiewicz and Webster, 2017; Ostwal and Chitawadagi, 2004).

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 (Amadi *et al.*, 2012a; Nivetha, *et al.*, 2016).

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 (Scholz & Grabowiecki, 2007; Sharma and Ramesh, 2006).

The use of plastic materials has increased from 5 million tons in the 1950s to 100 million tons in the 2000s (Sharma and Ramesh, 2006; Amadi *et al.*, 2012a; Amadi *et al.*, 2012b; Ankit and Urmil, 2013).

The challenge of waste disposal has become one of the most serious environmental problems facing many cities in Nigeria (Amadi *et al.*, 2012b; Joel, 2015; Youcef and Ganesh, 2015).

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. 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 (Amadi *et al.*, 2012b; Sarang and Shubhankar, 2017; Ostwal and Chitawadagi, 2004).

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. 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 (Visser, 2006; Youcef and Ganesh, 2015; Raghatate and Atul, 2016).

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. This research will therefore harness the vastly available plastic wastes which has caused environmental menace for economic purposes.

**Study Area**

The map of the study area, Lagos State is shown in Figure 1 while the geology map of Lagos State is contained in Figure 2. It 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. Quaternary sediments are recent deltaic sands, mangrove swamps and alluvium near the coast.

The raw materials were sourced from Offa municipality, in Offa Local Government Area of kwara State, Southwestern Nigeria (Figure 3).



Fig. 1: Map of Lagos State (Study Area)

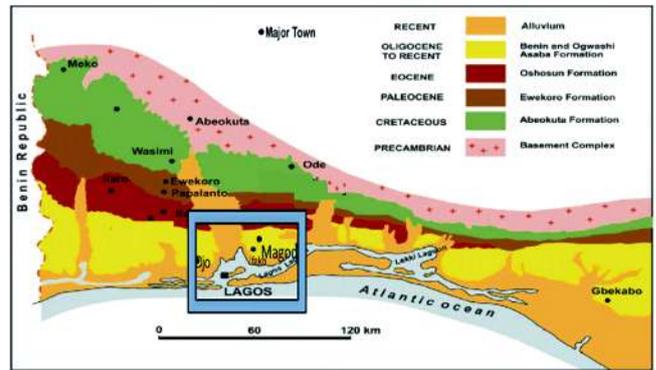


Fig. 2: Geology Map Southwestern Nigeria showing the Study Area (Lagos State)

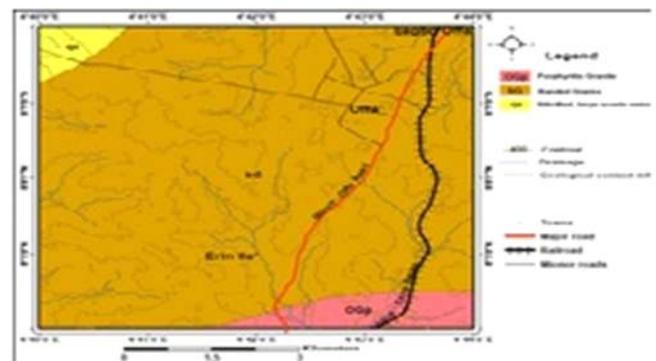


Fig. 3: Geology map of Offa Municipality where the Geomaterials (Granite Dust, Sand and Clay) were sourced

**Materials and Methods**

**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 sand was collected along Alagbaa River channel in Offa, Offa local Government, Kwara 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 around Owode market in Offa and has a specific gravity of 2.7. The clay was sundried, pounded (to loosen the particles) to a fine powder.

*Plastic Materials:* The plastic materials (PET and LDPE) were sourced from restaurants, campuses and Owode market- all in Offa municipality. They were washed and then shredded into very small pieces by a grinder at a local plastic processing outlet.

Other materials used are Hand gloves, nose masks, safety boots, 1 melting barrel, A spade with a metal shaft for starting of hot mix, Industrial gas as source of heat, Mould (200mm x 100mm x 75mm), Used engine oil for lubrication, Metal table for mould placement, Hand trowel, A Pyrometer.

### **Methods**

All the pavement block samples produced for this research work were molded from a metal mould 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.

#### **Mix Ratio**

- i. 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.
- ii. Plastic melt and sand:
  - 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.
- iii. Plastic melt and clay:
  - 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
    - 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.

#### **1. 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<sup>2</sup>

#### **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<sub>wet</sub>. The water absorption rate was calculated using the following Formula  
water absorption rate = (weight<sub>wet</sub> - weight<sub>dry</sub>)/weight<sub>dry</sub> ×100%

#### **3. 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.

#### **4. 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.

#### **5. Acid Test**

Block samples were digested with a weak sulphuric acid (H<sub>2</sub>SO<sub>4</sub>) 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, Interpretations and Discussions**

### **Compressive Strength Test**

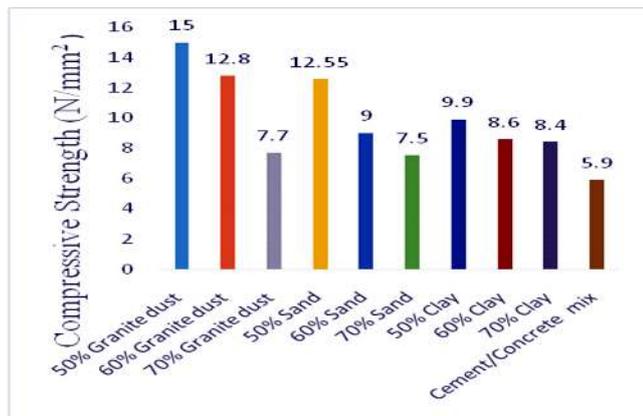
Table 1 shows the result for the compressive strength of the different samples represented on the bar graph in figure 2

The Compression test shows that the mix ratio 50:50

**Table 1:** Table showing the compressive strength of each of the 10 sample paver blocks

Samples	Load (N)	Compressive Strength (N/mm <sup>2</sup> )
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

(plastic melt: granite dust) has the highest compressive strength of 15.0N/mm<sup>2</sup> (Figure 2), a value which is almost three times the 5.9 N/mm<sup>2</sup> value of the cement derived pavement block, while other mix ratios equally have their degrees of variation.

**Fig. 2:** Bar Chart of Pavement Blocks at different ratio versus their respective compressive strength

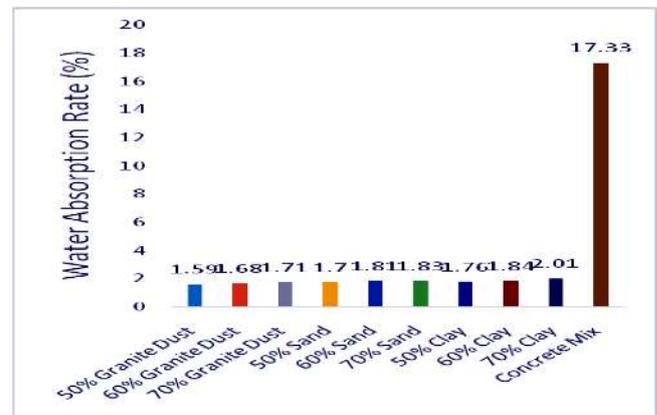
### Water Absorption Test

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

All the sample blocks produced from plastic melts have water absorption (WAR) values ranging from between 1.59% to 2.01% (Figure 3). All these values are abysmally lower than the W.A.R 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 supports the growth of algae, spirogyra and mosses on its surface.

**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

**Fig. 3:** 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. The lower WAR recorded by the plastic derived pavement blocks give them an edge in terms of efficiency and durability especially in water logged areas.

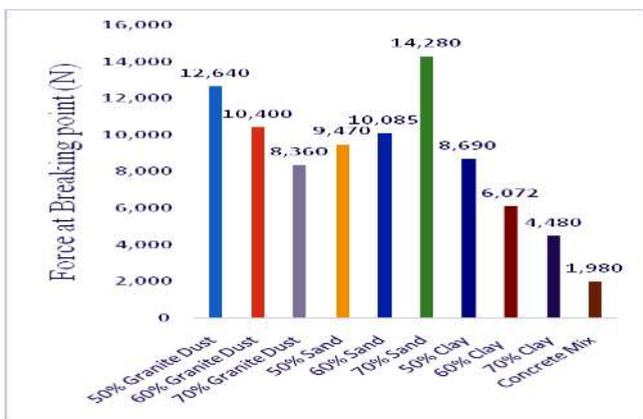
### Flexural Test

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 4). 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.

The Flexural test result shows that the mix ratio 70:30 (sand: plastic melt) has the highest flexural strength of

**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



**Fig. 4:** Bar Chart of breaking points of Geomaterials at different ratio

14.28kN, a value which is above seven times the 1.98kN 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.

*1. 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 (0C)

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**

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, durable and can withstand corrosion compared to the paver blocks produced from cement.

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