Available online at www.rajournals.in

RA JOURNAL OF APPLIED RESEARCH

ISSN: 2394-6709

DOI:10.47191/rajar/v7i2.04

Volume: 07 Issue: 02 February-2021

International Open Access

Impact Factor- 7.036

Page no.- 2846-2855

Investigation of the Use and Suitability of Plastic Waste for Molding Interlocking Stones in Port Harcourt

Ubong, I U.[1], Green, A. S.[2], Abam, T. K. S.[3]

[1] Institute of Pollution Studies, Rivers State University, Port Harcourt.

[2,3]Institute of Geosciences and Space Technology, IGST. Rivers State University, Port Harcourt.

ARTICLE INFO

Published Online: 18 February 2021

Corresponding Author: **Ubong, I U.**

ABSTRACT

Port Harcourt is known in local parlance as the 'Garden City' of Rivers State. This is so tagged because of the overwhelming presence of trees (Green Life) and flowers in the Metropolis. But today, it is different as the streets, gutters, rivers and the environs are littered with all types of plastic waste (MSW). These municipal solid wastes (MSW), are indiscriminately dumped at different locations in the Garden City. Plastics constitute a major component of these wastes; thus, this study was aimed at Investigating the Use and Suitability of plastic waste for molding Interlocking stones in Port Harcour*t*. In this study, samples of plastic wastes (bottles, cups, plates, spoons, and cellophane bags), were collected randomly at selected locations in Port Harcourt City. The area of study covered GRA Phase 1, 2, and 3, Old GRA, Diobu axis, and Port Harcourt main town. These plastic wastes are (PET-Polyethylene Terephthalate) which after collection were weighed and mixed with fine grains of sand (4 kg). The plastic waste samples of 5, 10 and 15 kg were used to mix with fine grains of sand of 4 kg. The mixture was heated under very high temperatures and melted to form a homogeneous mixture. The resultant homogeneous mixture was then poured into different molds of the same sizes (1.32×10^{-3} M^3). In another reaction, fine grain of sand of 4 kg was mixed with cement of 5, 10 and 15 kg respectively. The mixtures were poured into molds of the same sizes (1.32×10^{-3} M^3). The strengths of the two different interlocking stones (paver) were measured and compared to confirm which one of them has a better compressive strength for 7, 14 & 28 days. A total of fifty-four (54) molds were used of which twenty-seven were made from plastic waste and the other twenty-seven from cement. The compressive strength of Interlocks made from the two substances were measured and compared. The result showed the compressive strength of Interlocks made from 5, 10 and 15 kg of plastic wastes and 4 kg of sand for 7, 14, and 28 days being comparable to that of cement. The t-test showed that there is no significant difference between the strength of mold made by cement and that of plastic waste. This implies that Plastic Wastes can act as a suitable alternative material to cement for the making of interlocking stones as it has excellent binding properties like cement. This study recommends proper management and disposal of wastes to reduce environmental degradation.

KEYWORDS: Plastic Waste, interlocking stones, pavers, molds, cement, sand, compressive strength.

1.0 INTRODUCTION

Plastics wastes are commonly found on the streets, drainages, rivers, creeks and the local dumps. This causes serious nuisance to the Garden City of Port Harcourt. Our gutters are blocked as a result causing flooding during rainfalls. Today, our drainages and rivers are gradually being overtaken by these Plastic Waste. The fish and other aquatic life will find it difficult to breathe as a result of Plastic Waste covering thereby limiting dissolved oxygen in the water.

One of the major problems of Urbanization is solid waste generation. This problem has become severe over the last ten years (Onibolun, 1989). Increased population results in increased waste generation arising from increased consumption of a huge range of products and packaging of these products. It also causes huge Municipal Solid Wastes, along major streets, roads, stream channels, river banks and open spaces. These are very common in Nigeria, and particularly Port Harcourt (Ogbonna *et al.,* 2002). It is important to note that the Government on several occasions, has engaged the services of various Agencies/Contractors to evacuate theses huge wastes generated, but it has not been entirely successful in terms of evacuation. Since the Government finds it very difficult to effectively evacuate combine (Non- segregated) solid wastes, it becomes necessary to look for ways to adequately segregate and evacuate these solid Plastic Wastes. In this study, investigation covered why waste generated are not segregated and disposed of or given to companies who may need them as essential materials for recycling or formation of other products.

Plastic wastes (in forms of bags, bottles, plates, etc) are dumped on the Streets (center pavements), Gutters or drainages, rivers, Streams of Port Harcourt. This calls for serious concern and the need for an intervention measure before it is too late. Interlocking Stones, bricks and a lot of other products can be made by the recycling of these Plastic Waste or cellophanes. This study is aimed at, investigating the use and suitability of Plastic Waste for molding interlocking stones in Port Harcourt. The study also examined the management of these plastic wastes generated across Port Harcourt Metropolis. A joint study by the Rivers State Ministry of Environment and Agip Oil Company Limited, Port Harcourt, estimated 342,352 metric tons of municipal solid waste generated in Port Harcourt metropolis in the year 2001 as compared to 273,095 metric tons in 2000. This represents 25.4% in waste generation rate in the Port Harcourt city. The deplorable state of sanitation in Port Harcourt and its environs, has been attributed to politicians' inadequacies and efficiency in the areas of poor management policies on products and the Military abolishing the Monthly environmental sanitation exercise, which was an effective effort for over ten years. The 1991 population census figure for Port Harcourt metropolis, was 653,183, and the nationally adopted average annual growth rate for Rural areas is 2.5 % and 3.0 % for Urban areas, with an estimated municipal solid waste of 1,393,880 kg/day (Federal Office of Statistics, 2003). Each of the zones in the metropolis generates about 199,126 kg/day with approximately 1.03 kg/person/day (Gobo, 1998, Ayotamuno & Gobo, 2004). In Port Harcourt, plastic waste has become a major problem. They block drains, pollute rivers, creeks and wreak havoc on the environment.

Plastic wastes contain Polycyclic Aromatic Hydrocarbons which when melted, can be changed into different forms. They take the form or shape of the containers in which they are put as they consolidate. Plastic waste bags and cellophane bags are a key factor to environmental pollution in the world today. It has been reported that plastic wastes can be effectively converted or recycled into useful building materials such as: Bricks, Interlocking Stones, Roof Tiles, railing sleepers, paving slabs, retaining blocks, etc. (Trey, 2009). In view of the research findings reported by various scholars, it has become necessary, to adopt the use of additional concrete mixture, “Hard Core”, otherwise called chippings to the mixture of the melted plastic waste to get three times stronger Interlocking stones. Non-segregated solid waste can be best segregated at the point of generation. When this waste has been adequately segregated, licenced agencies should be engaged by the Government.

The degraded physical environment, harbor, encourage the production of flies, fleas, mosquitoes, rats, and other disease vectors, which could cause several chronic diseases such as; Lassa fever, malaria, filariasis, yellow fever (Ekuge, 1998). The constant presence of litters on the streets is psychologically depressing to the city dwellers and tourists that visit the city and so the management of these wastes cannot be compromised. The unsustainability and wasteful utilisation of resources which give rise to pollution of rivers and lakes, result in huge fish and other aquatic life destruction. This is due to increased organic load and the concomitant depletion of dissolved oxygen in these aquatic environments (Sundaresan, 1977; Ajiwe *et al.,* 2000; Phiri *et al.,* 2005 & Emongor *et al.,* 2005). Plastics is any synthetic or semi-synthetic organic polymer. Plastics can be made from any organic polymer, most industrial plastics are made from petrochemicals. Thermoplastics and Thermosetting polymers are the two types of plastics.

All over the world, plastics are used as casing materials, insulators, protective materials, instrumentation materials, coating, packaging and a lot of other fundamental uses. From these various uses of plastics, a lot of waste are generated due to their synthetic or semi- synthetic nature. As a non-biodegradable substance, it becomes highly difficult to decay. It has a half-life of over hundred years or more before it can decay.

The huge deposit of debris (wastes plastics) littering the streets, gutters, rivers, and drainages in Port Harcourt, call for great concern. Port Harcourt has always been known to be the garden city of Rivers State, but this now appears to be a mirage. The concept of converting the plastics waste to wealth is also one of the major motivations to this research. Waste generation has created a lot of challenges in the environment; so, there is need to create awareness to the public about the actual state of the dump sites in our cities. The aim of this research was to investigate the use and suitability of plastic waste for molding interlocking stones in Port Harcourt. It also examined the compressibility of the molds made of plastic waste and that of cement.

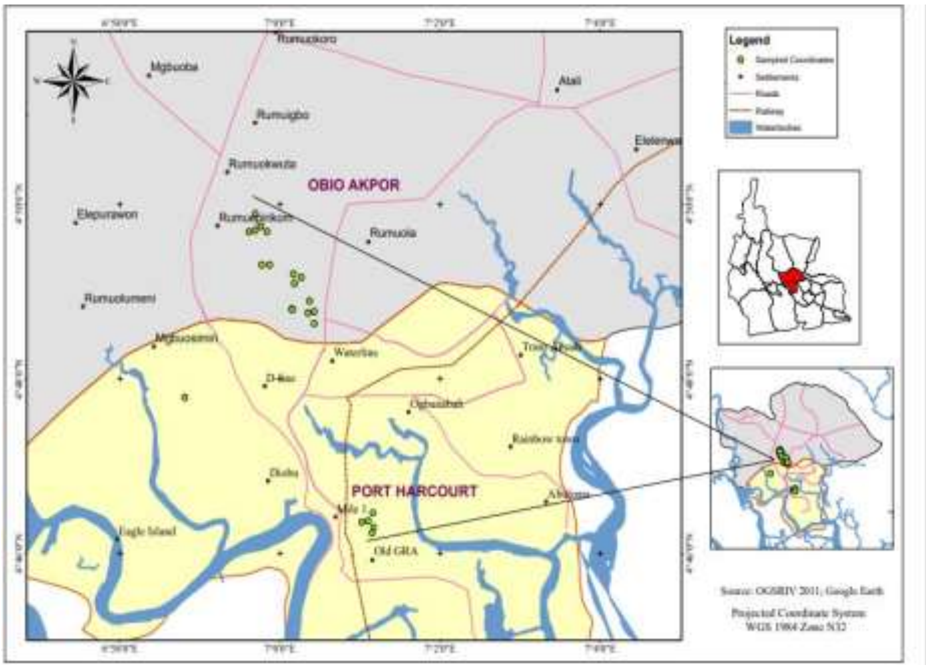

Fig. 1: Plastic Waste Study locations in Port Harcourt metropolis

2.0 STUDY AREA DESCRIPTION

Port Harcourt is located within the Niger Delta environ at the southernmost part of Nigeria (Fig. 1). It is bound by Longitudes 6̊ 56′ to 7˚ 07′ E and Latitudes 4˚ 44′ to 4˚ 52′ N of the Equator; with a plain topography and about 5 m above sea level. This plain is well drained and provide several connections with the sea (Gulf of Guinea) by a large number of creeks and channels. About five streams drain the Port Harcourt Metropolis connecting to the several creeks that lead to the sea. In Port Harcourt, the climate falls within the sub-equatorial climate belt. The Humidity and Temperature are high throughout the year. Two distinct seasons exist – the Wet and Dry seasons, with 70 percent of the annual rains falling between April and September, while 22 percent spreads in the three months of September to November. The driest month are from December to March (Gobo, 1998), with humidity oscillating between 80 percent and 90 percent.

Fuglsan (2014), a masters' Student in Science Engineering, at the Technical University, Denmark (DTU), used old plastic bags to make bricks for building house in India. In her experiment, titled: "Green Challenge", she won the best prize during her project. These bricks have the ability to withstand six tons of pressure (Kasoumloum, 2016). "Plastic cups melted in wood fires, have been reportedly used to heat homes during the winter. The mixed melted plastics with water are shaped into small balls and made into plastic concrete (building Bricks), gotten from landfills (Trey, 2009). Henry (2009), introduced a way to reuse Plastic Waste as an aggregate to cement. He crushed Landfill bound plastics and mixed it with Portland cement to make Bricks for building. Describing his project, Henry asserted the possibility of using graduated, postconsumer plastic wastes as the aggregate to concrete which has been researched upon. In this study, unlike cement, which can be universally mixed with no adverse effect, the discovery showed that the resulting product is as strong as the conventional concrete (between 3000 and 5000 psi). As a result, using plastic rather than the conventional aggregate is of a better value. Thus, the mining of new material to serve as aggregate is not necessary." Jeevan et al. (2019), asserted that concrete is the most widely used construction material in the world. Using waste and recycled materials in concrete mixes for paver blocks is becoming increasingly important to manage and treat both the solid waste generated by industry and municipal waste. The blocks produced were rectangular in shape and are of the same size as the bricks. He observed that for five decades now, the block shape has been relentlessly developed, from non-interlocking to somewhat 3 interlocking, to completely interlocking to multiple interlocking shapes. Plastic waste which is nonbiodegradable is rapidly growing in the surroundings and becoming a threat to environment in many aspects. Kasouloum (2012), a Cameroonian, during the Arts and Crafts Expo (AFAC), which took place at the Eagle square, Abuja, presented a research project on recycling waste polythene bags and plastics and making bricks out of them using sand. Kasoumloum, used Plastic Waste instead of cement to make 'eco-friendly' paving slabs in Cameroon. His initiative was to create jobs to at-risk street children. Kognole et al. (2019), worked on the "utilization of plastic waste for making Plastic Bricks". He demonstrated the use of plastic waste in making plastic Bricks. The research concluded that plastic waste is available everywhere in the eco-system and can be used in making bricks. Plastic sand bricks can reduce environmental pollution. It can also reduce the usage of clay in making bricks. Plastic sand bricks can give the customer an affordable cost rate. Water absorption of plastic sand bricks are zero percent. It is very useful for the construction industries as compared to Fly Ash bricks and 3rd class clay bricks. Thorat, et al. (2019), carried out 'literature review on different plastic waste materials and sand in making Paver Block'. He discovered that used PVC Plastic Waste mixed with M-Sand of fine aggregate in percentages of 0, 10, 20 and 30 for 7 and 21 days (curing age) were used. The research revealed that: Plastic Waste can be re-used in the molding of paver blocks. That plastic waste paver has a better compressive strength compared to the conventional concrete pavers.

Mivetha, *et al.* (2016), presented a paper on the production of Plastic Paver block from Solid Waste (Quarry Dust, Fly ash and PET-Polyethylene Terephthalate). The study examined the possibility of using plastic wastes as a binding material instead of cement in the manufacturing of paver blocks. Plastics, is a Polyethylene terephthalate. Plastic waste was collected to melt and mixed with a varying proportion of solid waste fly ash and quarry dust (PET 25-35 % fly ash 25 % and quarry dust 40-50% in weight). The measurements of physical and mechanical properties showed that plastic waste paver blocks gave a better result than concrete paver blocks. Onugha (2014), examined the effect of Waste Management on Environmental Sustainability in Port Harcourt. The result revealed that: out of the four independent variables correlated and regressed with the criterion measure of sustainable development, waste Regulation was the best predictor. Ogbonna *et al.* (2007), highlighted the urban solid waste generation in Port Harcourt metropolis and its implications for waste management. So far, studies on compressive strength of molds have not been done and reported in Port Harcourt and this necessitated this study.

3.0 MATERIALS AND METHODS

Plate 1: Dump Site 1 at Shell Location in Chinda/Elijiji Community, PHC.

The following steps were adopted in the preparation of the materials needed for this research:

1. Sampling sites and Sample collection

The study areas covered some parts of Port Harcourt and were randomly selected as they were in the heart of Port Harcourt city and in the most populated areas of the city. Sampling covered some houses within the Old GRA Phase 1, II, III, Diobu areas and Port Harcourt main town. Samples were also collected from some market places and Landfills located within the sampling areas.

A recognizance Survey of Dump Sites was carried out. Some dumped sites were identified and used as shown in Plates 1 & 2.

2. Sample Type, Collection and Preparations

The major sample type is plastics waste of all forms as generated by the different consumers of goods by the different households and industries (manufacturing, Petrochemical and Petroleum Oil Industries), Factories, commercial centers, and various other generating centers or outfits located within these study areas. Sharp sand of very fine grains – 0.5 to 1.5 mm was procured and used. The Plastic waste samples were collected from different houses, landfills, market places and supermarkets of the different locations. The samples were bagged after proper sorting and washing. These bags were weighed according to specifications.

3. Sample preparation

The samples were carefully sorted before putting them into the weighing cellophanes bags. The PET bottles, cellophanes bags, and other forms of thermosetting and thermoplastic Hydrocarbons were separated from Iron contamination, papers, and any form of unwanted materials (non-recyclable substances) and the sorting was done manually.

Plate 2: Dump Site 2 at Shell Location in Chinda/Elijiji Community, PHC

Fine grains of sand of 0.5 -1.5g were collected and adequately dried by putting them in an oven. An approximate weight of 36 kg was used. Approximately 30 kg of plastic waste were used for this experiment. It was weighed with a weighing balance. The same was applicable to the cement where a total of 54 molds were used for this research work. Less than ½ bag of cement, which is approximately 35 kg was needed for the work. A fabricated burner and pot were constructed to melt the sand and Plastic Wastes. 10-15 litters of water were used.

The bagged sample was then subjected to proper washing to remove all forms of debris accompanying the waste. The clean plastic waste was then put on the weighing machine and adequately weighed with minimum error. The different molds of the same designs were properly washed and ready for use. It is important to note that for comparison purposes, the same quantity of Plastic Waste used was same for the cement. A localized furnace was constructed and used to heat up the mixture of sand and plastics. These Plastic Waste were weighed after collection on a weekly basis. The Plastic Waste generated from homes, Industries and various other means and dumped on our streets and gutters can be converted to something useful. Thus, reducing the generated waste, will greatly reduce environmental pollution (basically air and water pollution), across Port Harcourt and Rivers State at large.

Materials

Other materials used in this research were as follows: Sharp Sand of very fine grains – 0.5 mm to 1.5 mm; Head Pan to measure the amount of Plastic Waste and the sand. All forms of Plastic Waste, especially cellophanes; a weighing scale; molds of different designs and sizes; Cement (for the basis of comparison); locally made burner constructed to homogeneously mix the substances or ingredients.

Method of production of the different Interlocking stones

The sand of very fine grains (0.5 – 1.5 mm), was adequately dried in the locally constructed furnace and poured into a basin or on the top of a mat, placed on the ground. A bag of cement and a 20-litter bucket of water was used. A total of 54 molds were made for the work. The cleaned bagged Plastic Waste were weighed in the range of 5, 10 and 15 kg. The same measurement was made for the cement. A constant weight of 4 kg of sand was weighed and used. As soon as the locally constructed furnace was set up, the sand was poured first to further dry it up and slowly the 5 kg of plastic waste was added and stirred continually until a homogeneous mixture was achieved. The tap was turned open to allow the homogeneous liquid mixture flow out into nine molds. The mixture was allowed to cool in the atmosphere for a period of time. The same process was repeated with a constant weight of 4 kg of sand and 10 kg of plastics waste. The resultant homogeneous mixture was poured into another nine molds. The left-over was poured into any other container. This same process was done for a 15 kg of Plastic Waste and 4 kg of sand. The resultant mixture was also poured into nine molds. The leftover was discarded. These molds of Interlocking stones were kept for a period of 7, 14 and 28 days to determine the different strengths of the molds. Similarly, the conventional interlocking stone was made of cement and sand mixed with water. Thus, in this second experiment, no heat was involved. The same measurement of cement (5, 10, and 15 kg) were mixed with the constant weight of sand, and water. These different mixtures of 5, 10 and 15 kg of cement were poured into nine molds each. The resultant interlocking stones were kept for 7, 14 and 28 days respectively.

Quantification and Analysis Testing of the Strength of the different interlocks:

The finished produced samples of interlocking stones were weighed with a quality measuring scale or instrument, in grams or kilograms. The data gotten were represented in tabular forms and Bar Chats. These different interlocking stones (pavers) were then taken to the laboratory to confirm their different strengths. T-test was used in analyzing the significant difference between the strength of interlocks produced from plastic waste and cement.

4.0 RESULTS

The results are presented in Tables 1 – 9 and Figs. 1- 5. Keys used are presented thus:

A^1, B^1, & C^1: 1st molds made from the mixture of 5 kg of Plastic Waste and 4 kg of sand for 7, 14, & 28 days.

A^2, B^2, & C^2: 2nd molds made from the mixture of 10 kg of Plastic Waste and 4 kg of sand for 7, 14, & 28 days.

A^3, B^3, & C^3: 3rd molds made from the mixture of 15 kg of Plastic Waste and 4 kg of sand for 7, 14, & 28 days.

A^4 , B^4 & C^4 : 1st molds made from the mixture of 5 kg of cement and 4 kg of sand for 7, 14, & 28 days.

A^5 , B^5 , & C^5 : 2nd molds made from the mixture of 10 kg of cement and 4 kg of sand for 7, 14, & 28 days.

A^6 , B^6 , & C^6 : 3rd molds made from the mixture of 15 kg of cement and 4 kg of sand for 7, 14, & 28 days.

Table 1: Weight of cement, plastic waste and constant weight of Sand in kg.

S/No.	Quantity of Plastic Wastes	Quantity of Cement	Quantity of Sand
Type of molds	7 days N/mm^2	14 days N/mm^2	28 days N/mm^2
1	5	5	4
2	10	10	4
3	15	15	4

Table 1 shows the varying weights of cement, plastic waste with a constant weight of sand (kg) used for the study.

Table 2: Compressive Strength of interlock made from 5 kg of plastic wastes and 4 kg of sand for 7, 14 and 28 days respectively.

Type of molds	7 days N/mm²	14 days N/mm²	28 days N/mm²
Type A[1]	5.65	7.41	16.38
Type B[1]	6.70	7.22	12.28
Type C[1]	6.36	7.25	12.28
Average	6.24	7.29	13.65

Table 2 showed data on compressive strength of Interlocks made from 5 kg of plastic waste and 4 kg of sand for 7, 14, and 28 days. The result also showed varying compressive strength with types of Interlock (A[1], B[1], and C[1]). The strength ranges from 5.65-6.36 N/mm² with an average strength of 6.24 N/mm². The weight result also showed that irrespective of the type, strength increases from 7 days to 14 days to 28 days where the maximum strength was obtained.

Table 3: Compressive Strength of interlock made from 10 kg of plastic wastes and 4 kg of sand for 7, 14 and 28 days respectively.

Type of molds	7 days N/mm²	14 days N/mm²	28 days N/mm²
Type A[2]	6.43	8.55	17.20
Type B[2]	7.42	8.46	14.74
Type C[2]	7.77	8.06	15.83
Average	7.21	8.36	15.92

Table 3 presents results for 10 kg of plastic waste used, with a constant weight of sand for 7, 14 and 28 days. The different types of interlocking stones had varying compressive strength ranging from 6.43 -7.77 N/mm² with a mean of 7.21 N/mm². The Strength increases with number of days stored from 7, 14 to 28 days.

Table 4 showed results for the use of 15 kg of Plastic waste with 4 kg of sand for 7, 14, and 28 days. The same variability of strength was observed for different types of interlocking stones. The strength varied from 7.14 - 9.18 N/mm² with an average of 8.27 N/mm² with the types of interlocks. It was also observed that the strength increases from 7.14 N/mm² to 9.12 N/mm² in 14 days and to 18.83 N/mm² in 28 days. So, the longer the days, the stronger the interlock.

Table 4: Compressive Strength of interlock made from 15 kg of plastic wastes and 4 kg of sand for 7, 14 and 28 days respectively.

Type of molds	7 days N/mm²	14 days N/mm²	28 days N/mm²
Type A3	7.14	9.12	18.83
Type B3	8.48	11.29	16.37
Type C3	9.18	12.09	17.20
Average	8.27	10.83	17.47

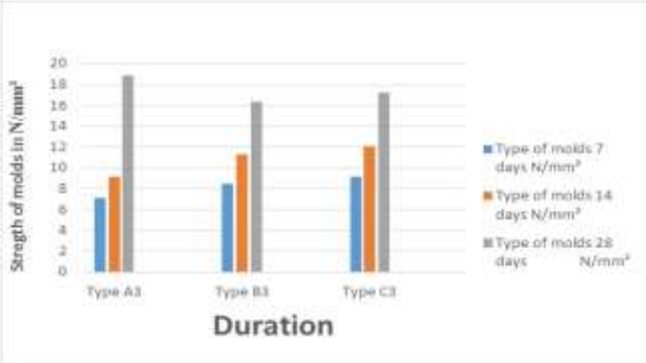

Fig. 1: The Compressive Strength of interlock made from 15 kg of plastic waste and 4 kg of sand for 7, 14 and 28 days

Table 5: Summary of the compressive Strength of different interlocks made from 5, 10, & 15 kg of plastic waste and 4 kg of sand for 7, 14 and 28 days respectively.

Quantity of Wastes	7 days N /mm²	14 days N/mm²	28 days N/mm²
5 kg of Plastic Waste and 4 kg of sand	6.24	7.29	13.65
10 kg of Plastic Waste and 4 kg of sand	7.21	8.36	15.92
15 kg of Plastic Waste and 4 kg of sand	8.27	10.83	17.47

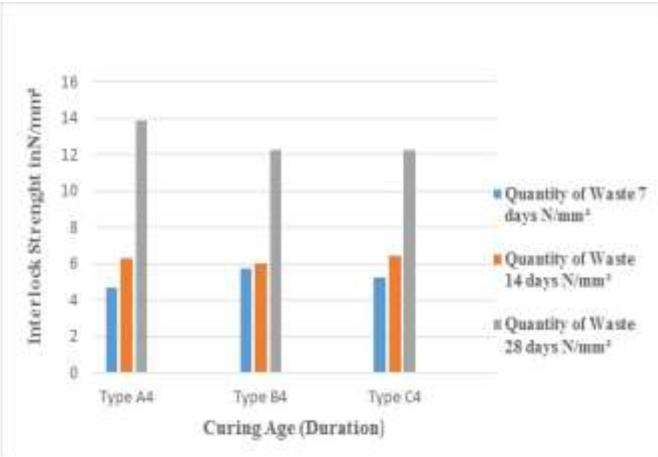

Fig. 2: The Compressive Strength of interlock made from 5 kg of Cement and 4 kg of sand for 7, 14 and 28 days

2. Construction with Cement

Table 6: Compressive Strength of interlock made from 10 kg of Cement and 4 kg of Sand for 7, 14 and 28 days respectively.

Type of Interlocks	7 days N/mm²	14 days N/mm²	28 days N/mm²
Type A5	5.36	5.99	17.20
Type B5	6.00	8.46	12.28
Type C5	6.36	6.06	13.10
Average	5.91	6.84	14.19

Table 6 presents results for 10 kg of cement used, with a constant weight of sand for 7, 14 and 28 days. The different types of interlocking stones had varying compressive strength ranging from 5.36-6.36 N/mm^2 with a mean of 5.91 N/mm^2. The Strength increases with number of days stored from 7, 14 to 28 days.

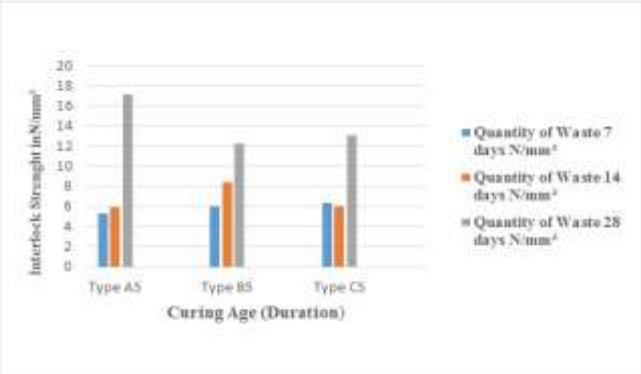

Fig. 3: The Compressive Strength of interlock made from 10 kg of Cement and 4 kg of sand for 7, 14 and 28 days

Table 7: Compressive Strength of interlock made from 15 kg of Cement and 4 kg of sand for 7, 14 and 28 days respectively.

Type of Interlocks	7 days N/mm²	14 days N/mm²	28 days N/mm²
Type A6	6.43	8.38	18.06
Type B6	7.77	10.68	16.37
Type C6	8.48	10.88	17.20
Average	7.56	9.98	17.21

Table 7 showed results for the use of 15 kg of cement with 4 kg of sand for 7, 14, and 28 days. The same variability of strength for plastics was observed for different types of interlocking stones from cement. The strength varied from 6.43 – 8.48 N/mm^2 with an average of 7.56 N/mm^2 with the types of interlocks. It was also observed that the strength increases from 6.43 N/mm^2 to 8.38 N/mm^2 in 14 days and to 18.06 N/mm^2 in 28 days. So, the longer the days, the stronger the interlock.

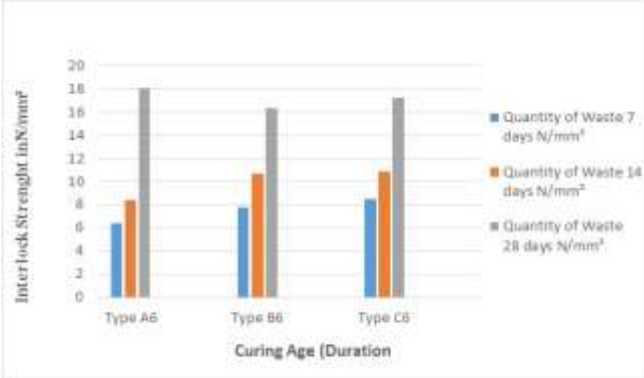

Fig. 4: The Compressive Strength of interlock made from 15 kg of Cement and 4 kg of sand for 7, 14 and 28 days

Table 8: Summary of compressive Strength of different interlocks made from 5, 10, & 15 kg of cement and 4 kg of sand for 7, 14 and 28 days respectively.

Quantity of Cement	7 days N/mm²	14 days N/mm²	28 days N/mm²
5 kg of Cement and 4 kg of sand	5.21	6.25	12.82
10 kg of Cement and 4 kg of sand	5.91	6.84	14.19
15 kg of Cement and 4 kg of sand	7.56	9.98	17.21

Table 8 summarizes the different interlocks type made from 5, 10 & 15 kg of cement with a constant weight of 4 kg of sand. It is evident from Table 5 that the strength of the interlocks increases with increasing weight of plastics waste 5 kg<10 kg<15 kg. It also increased with increasing days 7<14<28 days. This is represented in Fig. 5.

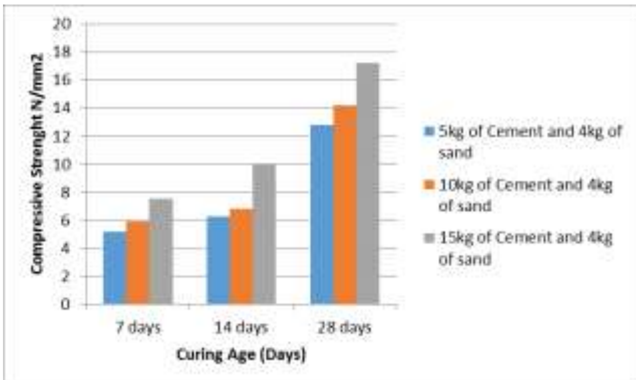

Fig. 5: Summary of comprehensive Strength relationships of Interlocks made of 5, 10 & 15 kg of cement.

T-test table showing comparison between the strength of molds of Plastic Waste and cement showed that if calculated t value (**t_{cal}**), is equal to or greater than the Tabular t (Critical t $_{0.05(2),16}$), the Null Hypothesis is rejected, meaning, 'there is significant difference'

($P<0.05$). If the Calculated t value (t_{cal}) is less than the Tabular t (Critical t $_{0.05(2),16}$), the Null Hypothesis is accepted, meaning, ‘there is no significant difference’, $P>0.05$)(Table 5). The result showed there is no significant difference in the Strength of interlock made with varying masses of cement and Plastic Waste with sand for curing ages during the period of study.

If $\mathbf{t_{cal} \geq t_{crit}}$ →reject the H_O accept H_A – There is significant difference.
If $\mathbf{t_{cal} \leq t_{crit}}$ →accept the H_O, reject H_A ----- There is no significant difference.
H_0: H_o is the Null Hypothesis; df is the degree of freedom; i.e. $\mu_1 = \mu_2$; $\mu1$= Plastic Waste and $\mu2$= Cement.

Table 9: T-test table showing comparison between molds of Plastic Waste and cement

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Strength of Interlock	Equal variances assumed	.012	.915	.520	16	.610	1.030	1.979	-3.166	5.226
	Equal variances not assumed			.520	15.985	.610	1.030	1.979	-3.167	5.227

If $\mathbf{t_{cal} \geq t_{crit}}$ →reject the H_O accept H_A – There is significant difference.
If $\mathbf{t_{cal} \leq t_{crit}}$ →accept the H_O , reject H_A ----- There is no significant difference.

From Table 9 above, the Levene’s test for equal variances assumed is NOT rejected, since its p-value is greater than 0.05, therefore subsequent interpretations will be based on Equal variances assumed. The critical value of t obtained at degree of Freedom (df), 16 is given **1.746**, Since the p-value **(= 0.610**) is greater than α (= **0.05**), also calculated absolute t (= **0.520**) is less than the t-crit (= **1.746**), we therefore do not reject the null hypothesis which states that:

H_0: There is no significant difference in the Strength of interlock Plastic Wastes with sand for curing ages during the period of study.

5.0 DISCUSSION

Table 1 shows the appropriate proportion of mixtures of the amount of Plastic Waste and cement to be used with sand. Table 2 results show that irrespective of the type of interlocking molds, the strength increases with days and varies with type of mold. The disparity of the strength of the molds for 28 days could be as a result of higher compatibility of particles of the first three molds.

Table 3 also shows that the more the weight, the higher the strength and that it varies with number of days. Similar observation was also made for 15 kg of waste, which had higher waste with molds increasing in strength. The higher the weight of plastics or cement the higher the strength. So, the strength was also dependent on number of days. Similar observation was made for cement. Strength was increased from 7, 14 to 28 days and also increased from 5,10 to 15 kg of cement. The t-test of these means showed that there is no significant difference. This means plastic waste can be used as an alternative to cement in the making of interlocking stones. The comparability of strength of the two materials implies the use and suitability of Plastic Wastes for molding interlocking stones. Based on the comparable strength of the interlocking stones made from Plastic Wastes and cement, one can say that Plastic Wastes are suitable for molding interlocking stones.

The study has shown that Plastic Wastes can be used as an alternative to cement in the making of Interlocking stones. From the results obtained, it can be concluded that plastic paver blocks can be used in the park, footpath and yards of the residential as well as commercial buildings because the compressive strength is sufficient for the smooth utility of user. Comparing the result of the interlocks made of Plastic Wastes and that of cement, it is evident that, those made of Plastic Wastes have relatively the same or close amount of compressive strength. Therefore, it can be concluded that Plastic Wastes is a suitable material used for the making of Interlocking Stones. The different results for the number of days (7, 14, & 28), show a progressive increase of the strength of the different interlocks. As the quantity of Plastic Waste increases, the strength of the Interlocks increases slightly.

An overview of the work carried out by Jaevan *et.al. (2019), on the* “utilizations of Plastic Wastes in manufacturing of paver blocks”, found that plastic paver block had almost equal strength as that of ordinary one, and that plastic paver blocks used in the park, footpath and yards of the residential as well as commercial building had compressive strength sufficient for the smooth utility of users. The findings from this study is in agreement with our findings.

Kasoumloum (2008), used Plastic Wastes instead of cement to make 'eco-friendly' paving slabs in Cameroon. In his experiment, he discovered the viability and effective usage of Plastic Wastes as an alternative to cement. Louis (2009), used Plastic Wastes as an aggregate to cement. He crushed Landfill bound plastics and mixed it with Portland cement to make Bricks for building. In his research, Plastic Wastes was used as a binding material to increase the compressive strength of the bricks. Mivetha, *et al.* (2016), in his research, concluded that Plastic Wastes is an alternative and binding material for molding bricks and various paver stones production. The findings of this study, based on compressive strength and t- test show and confirm the suitability of the use of plastic waste for molding interlocking stones.

The same weight of Plastic Wastes and cement were used (5 kg, 10 kg and 15 kg) to enable effective comparison of the two materials (Table 1). Varying weights were necessary to ascertain if the strength is dependent on weight. It was also clear from the result that there was variability of strength irrespective of the type of interlock molded. Increase in days increases the compatibility of the aggregates as the water dries up from 7 days to 14 to 28 days. It is also evident that the strength of the interlock is dependent on the weight of Plastic Wastes or cement used. The more the weight used, the higher the strength. This was common to cement and Plastic Wastes interlocks. Figs. 1 to 5 showed that the strength of the interlocks increases with increasing weight of plastics waste 5 kg<10 kg<15 kg. It also increased with increasing days 7<14<28 days. This therefore explains that the curing age of any mold, bricks and any other mixture increases with increasing number of days. This was observed for plastics and cement equally. This study compared only the strength of two different interlocks. It did not look at the different coloration or pigmentation and designs of the interlocks (pavers). It also did not look at quantifying the amount of Plastic Wastes generated in Port Harcourt.

Thorat, *et al.* (2019), carried out 'Literature Review on Different Plastic Waste Materials and Sand in Paver Block". He concluded that, plastics waste is suitable in molding paver blocks. The research also revealed that Plastic Waste paver has a better compressive strength compared to the conventional concrete pavers. This conclusion is also in agreement with the findings of this study.

6.0 CONCLUSION & RECOMMENDATIONS

The investigation and use of Plastic Wastes for the making of interlocking stones is a research that showed that Plastic Wastes can be used to make interlocking stones and that it acts as an alternative material for cement to the making of interlocking stones. It has demonstrated using T-test, that there is no significant difference in the strength of interlock made from Plastic Wastes to that of cement. This indicates that the quality of interlock obtained from Plastic Wastes is the same as the quality of interlocks obtained from cement.

In conclusion, Plastic Wastes is a suitable material for the making of Interlocks. It is therefore recommended that instead of discarding our plastic wastes, it can be collected from the point of generation to a company that will use them for the making of Interlocks and any other purpose. The utilization of Plastic Waste in production of paver blocks (interlocking stones) has productive (potential economic value) way of disposal of plastic wastes. It reduces plastics in municipal solid waste and significant reduction of land filling is possible if this project takes place on a large scale. It is strongly recommended that government should make policies that can stop or reduce the indiscriminate dumping of Plastic Wastes across the streets, drainages, creeks and rivers in Port Harcourt metropolis. Individuals can also build industries that can recycle these Plastic Wastes to interlocking stones or other uses. Agencies of Government, like RIWAMA (Rivers State Waste Management Agency), should enforce all government policies in this regard. There should be street to street, house to house collections of Plastic Wastes and transporting same to all recycling industries (end users), located within and outside Port Harcourt metropolis. Wealthy individuals can also establish companies for recycling purposes. This will create huge job opportunities in the society and reduce criminality.

REFERENCES

1. Ajiwe, V.I.E., Okeke, C.A., Akigwe, F.C. (2000). "A preliminary Study of Manufacture of cement from Rice husk ash Recovery of silver from Industrial waste, cassava solution effect. Vol, 21, issue 3 pp.80-90.
2. Ayotamuo, M.J. and Gobo, A. E. (2004). "Municipal solid waste management in Port Harcourt, Nigeria obstacles and prospects", Management of Environmental Quality: An International Journal, Vol. 15 No. 4, pp. 389.98.
3. Ekugo, E.I. (1998). "Public health and urban sanitation", Environmental News, Vol. 5 No. 7.
4. Emongor, V., Kealotswe, E., Koorapetse, I., Sankwasa, S. and Keikanetswe, S. (2005). "Pollution indicators in Gerone effluent". Journal of Applied Sciences, Vol. 5, pp.147-50.
5. Fuglsang, L.V. and Lotteo, K. (2014). Old plastics bags become bricks in Indian houses- DTU. Article in DTU., No, 9. www.Lisefvestergaard.com.
6. Federal Office of Statistics (2003), "General Demographic and Health Survey of Nigeria", Federal Office of Statistics Bulletin, National Population Commission, and Housing Census, Federal Ministry of Information and National Orientation, Abuja.

7. Gobo, A.E. (1998), Meteorology and the Environment, Afrika-Links-Books, Ibadan.
8. Henry, L. M. (2009). "Plastic Concrete: Building Bricks Made From Landfill Waste". Recycling Plastics. Retrieved 24 September 2009. https://doi.org/10.1371/journal.pone.0111913
9. Jeevan, G., Saurabh, S., Patil, B. M. and Bhutekar, S. B. (2019). "Utilization of Waste Plastic in Manufacturing of Paver Blocks". International Research Journal of Engineering and Technology (IRJET) Vol. 06. Issue 04.
10. John H. (2009), New Plastic Recycling Program, GOEX Corporation breakthrough- 'closed loops. 12, pp. 54-80.
11. Phiri, O; Mumba, P; Moyo, B H Z; and Kadewa, W (2005). Assessment of the impact of industrial effluents on water quality of receiving rivers in urban areas of Malawi. Int. J. Environ Sci Tech 2(3): 237-244.
12. Kasoumloum, P. (AFAC, 2012). African Arts and Craft Expo, Eagle Square, Abuja. https//allafrica.com: 2012/110709.
13. Kasoumloum, P. (2016). Plastic bags in Cameroon are turned into durable and sustainable floor tiles. An innovative way to deal with the thousands of plastic bags thrown away. TheCivilEngineer.org. Published in News on Products & Services. 11
14. Kognole, R.S., Kiran, S., Manish, P., Lokesh, P., and Udaysinh, S. (2019). "Utilization of Plastic waste for Making Plastic Bricks". International Journal of Trend in Scientific Research and Development (IJTSRD). Vol. 3, Issue: 4.
15. Mivetha, C., Rubiya, M., Shobana, S., Vaijayanthi, R. G., Viswanathan, M. E. and Vasanthi, M. E. (2016). "Department of Civil Engineering, Kongunadu College of Engineering and Technology", Trichy, India. Production of Plastic Paver Block from the Solid Waste (Quarry Dust, Flyash & PET). Vol. 10. Pp.321-340.
16. Morét-Ferguson, S., K. L. Law, G. Proskurowski, E. K. Murphy, E. E. Peacock, and C. M. Reddy. 2010. The size, mass, and composition of plastic debris in the western North Atlantic Ocean. Mar. Pollut. Bull. 60: 1873–1878.
17. Federal Office of Statistics, (2003). Nigeria Demographic and Health Survey. National Population Commission, Federal Republic of Nigeria
18. Ogbonna, D.N., Ekweazor, I.K.E., and Igwe, F.U. (2002). "Waste management: a tool for environmental protection in Nigeria", Vol. 31 No. 1, pp. 55-7.
19. Ogbonna, D.N., Amangabara, G.T. and Ekere, T.O. (2007). "Urban solid waste generation in Port Harcourt metropolis and its implication for waste management", International. Journal, Vol.18 No.1 pp. 72-9.
20. Onugha, C.A. (2014), "Effect on Waste Management on Environmental Sustainability in Port Harcourt." Journal of Nigerian Environmental Society (jnes), Vol.1 No.1
21. Onibokun, A.G. 1989. Urban growth and urban management in Nigeria. In: African Cities in Crisis. R.E. Stren and R.R. White, eds., Westview Press, Boulder, Colorado, pp. 68-111.
22. Sundaresan, B.B. (1977). Seminar on Industrial waste: Calcutta, organized by NEERI and calcutta Metropolitan Development Authority, Calcutta.
23. Thorat, P. R., Gosavi, R. D., Sutar, P. A., Gavane, K. M. & Phadtare Y. K. (2019). 'Literature Review on Different Waste Plastic Materials and in Paver Block'. International Journal for Scientific Research & Development. Vol.7, issue 01.
24. Tracking the movement of Plastic- litter-in-the ocean. (2018). Retrieved on 15th February, 2019, 10.53pm, from website: https//www.euractiv.com/. /why.
25. Trey. G. U. (2009). Recycling of Mining Plastic Waste into Bricks. Vol.7. pp 60-4 Machine to covert Plastic Waste to Bricks with the use of sand. Reuse Plastic Waste.