

Original Research Article

Recycling of Nylon and Plastic Waste to manufacturing Paving Stones

Abstract

Nylon and Plastics have become widely used materials in Nigeria, ranging from home commercial and industrial use. This is undoubtedly impacted positively on the economic situation of the country, most especially for the sachet water, pet bottle water, pet soft drinks producers and other manufacturing companies which use it as a wrapper or packaging bag. Managing the wastes generated through these industrial booms has become a concern because of its harmful environmental effects. In Nigeria, many companies and several individuals are involved in recycling these wastes either as raw materials for another plastic industry or as the recycling machine sellers. The researchers use a study site, Federal Polytechnic Offa, Kwara State, and Offa community for data collection. The data collected in the region is the primary data required to evaluate the quantities of nylons and plastics generated that can be used for the research work. Furthermore, experimental work was done to produce 250 prototype models of paving stones in a blocks mode. These stones were subjected to flexural, compressive-strength, water-absorption, oven and compressive tests. The results of these tests revealed that paver stones produced from plastic additives show more tensile strength, better water resistance, more resistance to corrosion and good heat absorber compared to the blocks constructed from cement. Plastic paver blocks also showed abysmally low water absorption than the cement blocks.

Keywords: Recycling of Nylon, Plastic Waste, Manufacturing, Paving Stones

INTRODUCTION

Global warming has become one of the significant concerns today. Recycling waste is one of the vital roles used in protecting the environment. The recycling of waste has become a much more profitable business today[1]. There are many kinds of recycling waste and recycling business ideas on industrial output. However, while considering recycling as a venture, a few requirements are needed, making a choice enhance visibility studies, to know what type of waste to recycling since there is plenty of garbage that demands recycling like household, construction, electronics waste and so on [2]. Therefore, having deep knowledge of the recycling process enables the researcher to know what kind of machines and tools need in the processing phase. Marketing research is one of the critical factors that can allow the sustainability of waste recycling ideas to succeed. The whole process helped protect the environment and, on the other end, earned profits [3].

The need to recycle nylon (sachet water nylon) and plastics in our environment as an institution has brought about the innovation of using them as raw materials for manufacturing paving stones. Paving stone is versatile, aesthetically attractive, functional and cost-effective and requires little or no maintenance if correctly manufactured and well fixed. Most concrete block paving stones manufactured in Nigeria also have performed satisfactorily [4]. Still, two main areas of concern are an occasional failure due to excessive surface wear and variability in the strength of the block. Naturally, resources are depleting worldwide while the generated waste from the industry, public places and residential areas is increasing tremendously. Sustainable construction development involves using non-conventional and innovative materials and recycling waste materials to compensate for the lack of natural resources and find alternative ways of protecting our environment from depletion [5].

Nylon and plastic wastes considered for use in this research come from the trash generated in our immediate environment, most especially in our institution and other nearby selected institutions where there is a high generation of the same. In Federal Polytechnic Offa alone, it is estimated that 2600 tons of nylon are generated annually at the temporary site alone, which adversely impacts man, animals and the natural habitat cycle of the environment. So it is necessary to safely dispose of these plastics to reduce their adverse effect on the environment and gainfully use them in manufacturing paving stones for economic advantages and a better institutional environment [6 - 7].

The nylon and plastics industries have developed considerably since the invention of various means for producing polymers from petrochemical sources. Plastics have a significant advantage in terms of low weight, durability and lower cost compared to many other materials. Still, the waste generated through these has become a source of concern because of the considerable quantity generated daily and its harmful effect on the environment. It necessitates recycling plastic wastes to free our environment from its harmful effects and turn them into useful material for manufacturing paving stones in road construction.

The needs for recycling nylon and plastic wastes as a substitute for cement in the manufacturing of paving stones in Federal Polytechnic Offa are basically to achieve the following objectives:

- To assess the volume of nylon and plastic wastes generated within the campus of Federal Polytechnic Offa.
- To safely recycle the generated wastes from nylon and plastics as a way of minimizing waste's havoc on the environment.
- To effectively use the recycled materials to manufacture paving stones for road construction within Federal Polytechnic Offa.

2.0 Literature Review

PVC recycling is a polyethene chloride used mainly in manufacturing pipes, tense and others. A rejected PVC can be taken and then treated for manufacturing PVCs. Chemical processes like pyrolysis, hydrolysis and heating are used to convert the waste into chemical components. However, the results of products like sodium chloride, calcium chloride, hydrocarbon products and heavy metal are used to produce new PVCs as viewed from many manufacturing processes or views for energy recovery [7].

Construction and reliable waste recycling are solid waste is non-biodegradable. Collecting this type of waste from the construction site and manufacturing it into a brick after complete treatment of the waste, compression is applied to produce a new shape that makes it more robust with a long life cycle. These bricks can be sold to new construction houses in proportionalities. It is applicable innock tiles, partition boards, cling materials and others, which require miniature fashionable painting [8].

Medical waste recycling is generally known to be dangerous. A large portion of waste like syringe needles can be recycled. Autoclaving, gas sterilization, chemical disinfection, microwave, irradiation, thermal inactivation and many more were the primary method used to recycle [3], [8].

There is the possibility of the intoxicating kitchen without even realizing the action. All activities like cooking, cleaning and eating produce a significant level of waste. In most cases, cooking utensils were disposed of as a waste, commonly recycled since most of the utensils were products of steel, copper and iron. So, when recycling process can be used to produce new utensils and sell them to other kinds of businesses.

The commercial for Glass recycling review for the improvement in the recycling of glass within the hospitality of businesses, hubs and restaurants sold over two hundred thousand the tones of glasses every year. Glass material can be easily melted down and remade into different kinds of shapes. Drinking glasses, moulding sculptures and glass fibre were most of the noble materials used in the world today. Once collected, it is broken into small pieces, crushed, soldered and cleaned. They can be molten into with another constituent-like sound which can be moulded into the desired shape [9].

The use of nylon and plastics appear to have come to stay in Nigeria, as some people prefer it to other products when wrapping sundry items. For many, nylon is the go-to disposable container for preserving foods and other perishable items in the freezer [10]. It seems evident that this amount of material that isn't meant to break down can wreak havoc on the natural environment, leading to long-term issues for plants, animals, and people (Conserve Energy Future, 2018). Plastics have substantial benefits in their low weight, durability and lower cost relative to many other material types [11 - 12]. The indefinite period it takes for the average plastic bag to break down can be hundreds of years. Every bag that ends up in the country's woodlands threatens the natural progression of wildlife. Because the breakdown rate is so slow, the bag's chances of harmlessly going away are incredibly slim. Throughout the world, plastic bags are responsible for the suffocation deaths of woodland animals and for inhibiting soil nutrients [13-15]. There is no way to strictly limit the effects of plastic bags on the environment because there is no disposal method that will help eliminate the problem. While reusing them is the first step, most people either don't or can't base on store policies. They are not durable enough to stand up to numerous trips to the store, so often, the best that citizens can do is reuse them when following pooper

scooper laws [16]. "Nylon and plastic waste form part of the total waste generated in the state. Presently, Offa in Kwara State generates about 3 000 metric tons of waste daily. The researchers discovered that a lot of waste material in the environment could be recycled to make more useful items and serve many purposes. When you say waste to wealth, you are turning waste into items you can make money from, which is an extensive topic[17]. Burning of waste nylon and plastic bottles can cause air pollution. Poisonous gases such as carbon monoxide, furans and dioxins are released into the air. They can endanger public health, destroy the ozone layer and contribute to global warming. So how can we efficiently remove and manage the enormous heaps of waste nylon and plastic bottles around us without destroying our environment? Green recycling is the way forward" [18 -20].

3.0 Methodology

In this research, questionnaires and personal interviews were employed to collect data for determining the volume of nylons and plastics generated on a daily, weekly or monthly basis. The Enumerated Areas (EA) as targeted areas included six (3) higher learning institutions from each state. This enables the researchers to explore the most densely populated communities where nylon and plastic materials are regularly generated as waste.

The researcher covered permanent site and mini campus of Federal Polytechnic Offa. This enabled the researchers to calculate waste volumes, transportation means and average waste material collection points in the selected regions.

The selected areas include Federal polytechnic Offa campuses and the Offa community. The research takes fifteen (15) working days in each coverage area for three (3) months for data collection, transporting and conveying of research material from the selected region to the destination (Offa mini campus in Kwara State)

In return, the researcher collated and analysed data collected from the field. This will take duration of one year to complete the research work. The research findings will be published for future research work and as a source of business development for any potential Entrepreneur.

3.1 Study Area Description

Offa Kwara State (Figure 1), the sub-economic hub of Nigeria, was chosen as the case study because of the over si million population, many industries and the large amount of plastic waste generated daily. The sharp sand, clay and plastic wastes were sources in entire Offa.



Figure 1: Geology Map Southwestern Nigeria showing the Study Area (Federal Polytechnic Offa Kwara State).

Geologically, Offa 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 1). The granite dust was sourced from Offa in Kwara State (Figure 2) because of its availability in Offa community and its environment.

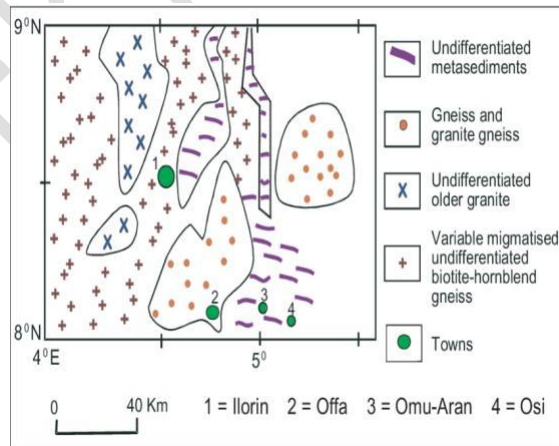


Figure 2: Geology Map of Parts of Kwara State Showing Offa (where granite dust was sourced).

3.2 RESEARCH MATERIALS

Cement Composition requirement

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 clean riverbed sand was collected and used for the research work. Clean and sharp sand was collected from the entire Offa community in Kwara State has a specific gravity of 2.65 and a fitness modulus of 0.4. It was oven-dried at the Federal Polytechnic Civil Engineering Department, Offa.

Granite dust

Granite dust was collected from a 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 Building Technology Department, Federal Polytechnic, Offa. It has a specific gravity of 2.57, fitness modulus of 2.41, a density of 1.85gm/cc and a void ratio of 0.42

Plastic Materials

The plastic materials (PET, HDPE and LDPE) were sourced from Offa communities in Kwara State. They were washed, air-dried and shredded into small pieces by a grinder at a plastic processing outlet to allow easy melting process.

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

3.3 The Research Method

The paving stone samples produced for this research work were moulded from a metal mould and wooden type. measuring 200mmx100mmx75mm. 80 Paving stones samples were produced for each of the different mix ratios. Clean, dried and 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

Paving stones were produced by mixing melted plastic and granite dust in the same proportion with three different sample of plastic and nylon in ratios of 50:50, this ratio is at the point at which proper paste was achieved, any further addition of stone dust would make it difficult to turn mix.

Cement and Aggregates Mix Ratio

The materials required composition (cement, sand and granite dust in the ratio of 1:2:4 respectively) were mixed thoroughly with a shovel until a uniform texture was achieved and portable drinking water was added to form the required texture was obtained.

- Water was added in a ratio not exceeding 0.6 to cement.
- The mixture was poured into lubricated mould
- The resultant mix was hardened and cured

Laboratory Tests

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

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 $200\text{mm} \times 100\text{mm} = 20,000\text{mm}^2$

Water Absorption Test

The weight of each oven-dried sample was measured as weight dry - The weight of each piece soaked for 24 hours was measured as weight wet.

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

Flexural Test

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

Oven Test

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

Acid Test

Block samples used were incorporated with a weak sulfuric acid (H_2SO_4) 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. This is done for every instance to represent the sample for each test carried out and presented in tables. Simple Bar graphs were used to show the data details from each test.

4.0 RESULTS AND DISCUSSION

Compressive Strength Test of the prototype mould

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 4 Sample Paver Blocks prototype.

Samples Size	Load (N)	Compressive Strength (N/mm ²)
50% Granite dust sample A	356,560	17.83
50% Granite dust Sample B	256,000	13.26
50% Granite dust Sample C	154,000	12.68
50% Sand	251,000	12.55
60% Sand	180,000	9
70% Sand	110,000	7.5
50% Clay	198,000	9.9
60% Clay	118,000	8.6
70% Clay	168,000	8.4
Cement/Concrete mix	118,000	5.9

The Compression test shows that the mix ratio of 50:50 (plastic melt: granite dust) has the highest compressive strength of 15.0N/mm² (Figure 4), a value which is almost three times the 5.9 N/mm² value of the cement-derived pavement block, while other mix ratios equally have their degrees of variation.

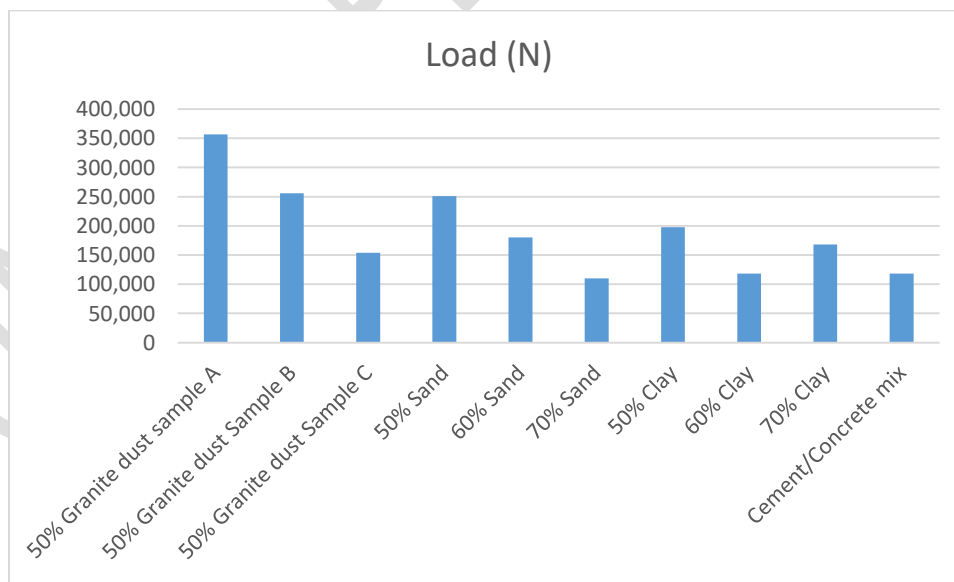


Figure 3: Bar Chart of Paving Stones at different Ratio versus their Respective Load

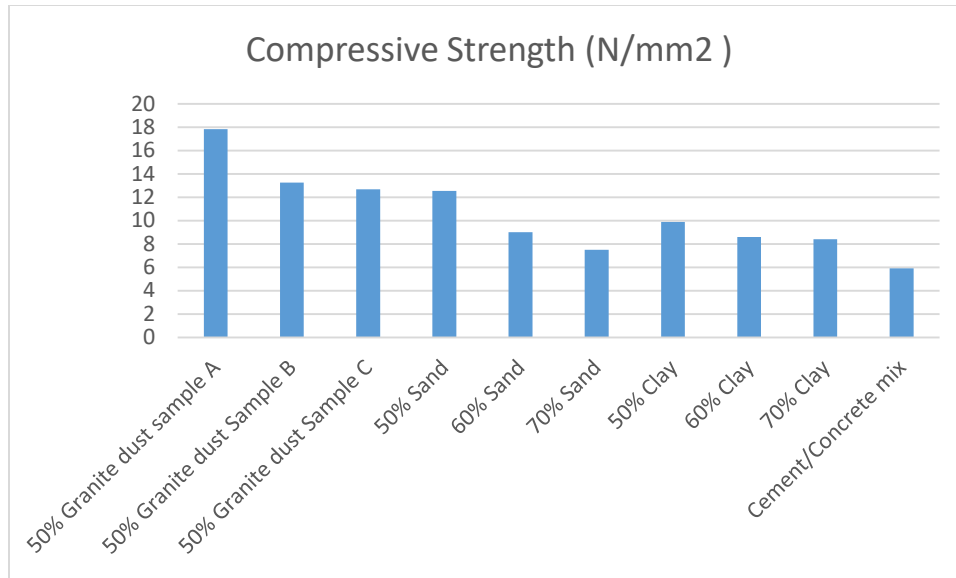


Figure 4: Bar Chart of Paving Stones at different Ratio versus their Respective Compressive Strength.

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 5 Sample Paving Stones.

Samples	Water Absorption Rate (%)
50% Granite Dust Sample A	1.59
50% Granite Dust Sample B	1.68
50% Granite Dust Sample C	1.71
50% Sand	1.7
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 melted plastics have water absorption (WAR) values ranging from 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 paving stones by alternate wetting and drying is more likely than in the plastic-derived paving stones. It

also underscores the reason why cement paver blocks support the growth of algae, spirogyra and mosses on its surface [19-20].

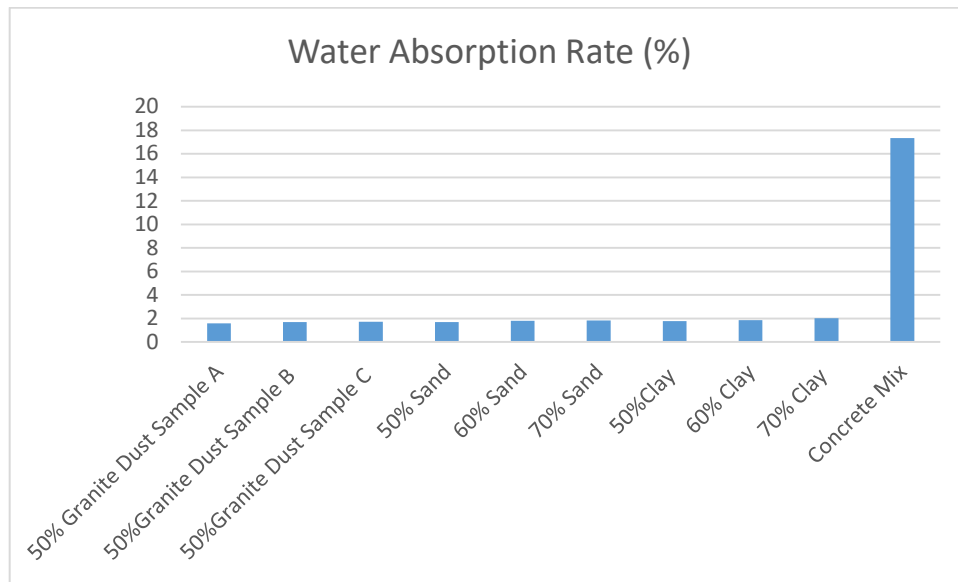


Figure 5: Bar Water Absorption Rate of Pavers from varying Ratio of Plastic Melts/Geological Materials and Cement.

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 [21]. The lower WAR recorded by the plastic-derived pavement blocks gives 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 important to note that while forces at breaking point reduce with various material of Plastic and Nylon of the same mix ratio. This implies that, each of the materials has different chemical composition which determine their flexural quality and ability

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

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

Table 3 shows the Force at Breaking Points (N) of each of the 5 Sample Paver Stones.

Samples	Force at Breaking point
50% Granite Dust, Sample A	12,640
50% Granite Dust, Sample B	10,400
50% Granite Dust, Sample C	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

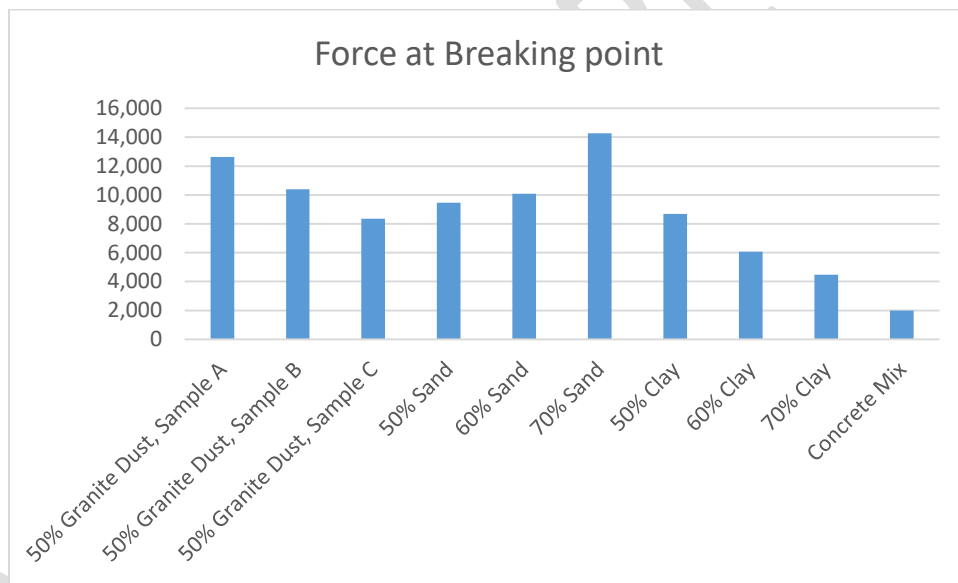


Figure 6: Bar Chart of Breaking Points of Geomaterials at Different materials in the same Ratios.

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 paving Stone fails. The results obtained from the oven test show that there was no visible change in the shape, size and rigidity of all the plastic-derived paving Stones at a temperature below 180°C.

Samples	Temperature of Failure (°C)
50% Granite Dust Sample A	180
50% Granite Dust Sample B	185
50% Granite Dust Sample C	185
50% Sand	180
60% Sand	185
70% Sand	185
50% Clay	200
60% Clay	205
70% Clay	210

Table 4: Compressive Temperature Falling Point for Plastic Paver Stone (°C).

CONCLUSION

The present study has efficiently and effectively demonstrated the application of waste plastic and nylon into useful constructional materials and reducing its harmful effects in our environment. The plastic wastes littered all over the environment can be converted into valuable constructional materials more economical and eco-friendly than cement based materials.

Based on the results of the various tests, the study has established that the plastic-derived paver stones are more rugged, more rigid, durable, low water absorption, and corrosion-resistant than paver stones produced from conventional Portland cement.

UNDER PEER REVIEW

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