

INVESTIGATING THE WATER ABSORPTION AND COMPRESSIVE STRENGTH OF CONCRETE BLOCK CONTAINING PLASTIC WASTE

Usman, A.B. and Jabba, E.U.

Department of Mechanical Engineering, School of Engineering Technology, Adamawa State Polytechnic Yola, Nigeria

Corresponding Email: abusman4u@yahoo.com

ABSTRACT

Plastic wastes are non-biodegradable waste, generating on daily basis creating environmental pollution and adversely affecting life style of human beings. This research aimed at investigating the water absorption and compressive strength of concrete block containing plastic waste aggregates. Sand and plastic waste was rationed and the blocks produced were subjected to water absorption capacity and compressive strength test. The sample blocks produced from plastic aggregates have water absorption values ranging from between 1.70% to 2.04% which are abysmally lower than the WA 17.70% value of the cement block. The Compression test shows that the control sample has the highest compressive strength of 13.2N/mm², a value which is almost twice the value of the plastic derived blocks. However, other mix ratios equally have their degrees of variations. A minimum strength 2.0 N/mm² was observed, but 10 and 20% plastic and sand ratio are more preferable in this experiment due to their strength. Furthermore, it will be environmentally friendly and feasible to enable reduction in poverty and ensuring a clean society. 10 and 20% plastic and sand ratio is recommended.

Keywords: plastic waste, water absorption, compressive strength, concrete block, sand

1 INTRODUCTION

Plastic products play a critical role in our lives and are being used in large quantities due to their durability, versatility, light weight, and low cost Plastic waste materials, generated in different sectors of the economy, such as agriculture, residential and commercial, automobiles, construction and demolition, packing materials, toys, and electrical equipment are growing rapidly and are either recycled, combusted (waste incineration), or disposed of Plastic waste consists mainly of low-density polyethylene (LDPE), high density polyethylene (HDPE), polypropylene (PP), polyvinylchloride (PVC), polystyrene (PS), and polyethylene terephthalate (PET) Polyethylene and polypropylene constitute the greatest portion of plastic waste [1]. The increase in the world population and subsequent living standards have caused a rapid increase in municipal solid waste generation of to up to 1.3 billion tons per annum reportedly, plastic waste is the third largest contributor of municipal solid waste The global production of plastic has increased, from 1.5 million tons in 1950 to approximately 359 million tons in 2018 and is attributed to a rapid rise in the packaging/wrapping sector Today, over 250 million tons per year are either landfilled or dispersed in the environment and an estimated 10 million tons per year end up in the oceans. Considering an increase of 9–13% of plastic waste per year it is predicted that billions of tons of plastic could be produced by 2050, of which the greatest portion could go to landfills or be dispersed, both in the land environment and in the oceans. Plastics can be made to different shapes when they are heated. It exists in the different forms such as cups, furniture's, basins, plastic bags, food and drinking containers. Globally, people for their daily needs use plastic and polythene bags because of its ease, cheaper and

convenience but which are hazardous to environment causing land pollution [2]. Plastic is a versatile material with wide applications. Its usage and latter disposal have become a problem due to the high volume of waste and the huge environmental impact they have, not only for the human population, but also for ecological systems [3]. Most municipal waste is either burned, dumped or buried on vacant lots, threatening the health and welfare of the general population [4]. Solid waste management is one of the major environmental concerns in our country nowadays. Waste management in respect to plastic can be done by recycling. Recycling the plastics has advantages since it is widely used and has a long service life. Because the amount of sand required to making block is large, the environmental benefits are not only related to the safe disposal of bulk waste, but also to the reduction of environmental impacts that arise due to burning of plastics. This research therefore harnessed 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.

2 LITERATURE REVIEW

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 [5, 6]. 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 reheated to form other plastics while thermoset plastics once melted, cannot be re-molded into other shapes after they have solidified [7]. 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 [8, 9]. 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 [10]. 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 [11, 12]. 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 [13]. 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 [7, 13]. 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. Overtime, research in developing countries to create strategies to mitigate contamination with these reusable polymer residues has increased [14] used low density polyethylene bags (LDPE or PE-LD) as a total cement replacement to prepare plastic paver bricks with good results in compressive strength, melting point and water absorption. [15] used waste plastic bags to completely replace conventional cement in concrete pavement blocks and improve desired properties for road pavement. Pavement blocks made with LDPE plastic and sand wastes, with a 5% coarse aggregate, showed better mechanical properties, flexibility and resistance to water absorption. Thousands of tons of waste are dragged into rivers and oceans, greatly damaging flora and fauna, as well as ecosystems that are fundamental to breed and preserve coral species, algae and fish in different ecological contexts. [16] tried turning plastic waste into pavement blocks in Ghana, and determined the physical and chemical properties of well sand, sea sand, plastic waste and building blocks. The increase in plastic composition improved the average penetration resistance of both pavement blocks, and results suggest that turning plastic waste into pavement blocks is feasible and can help reduce the rapid accumulation of waste in Ghana. In Colombia, educational and pedagogical campaigns in environmental policies are being directed to the regulation, use, management and recovery of solid waste of industrial origin; thousands of companies and microenterprises are making systematic use of polymers that can be

recovered and processed as raw material for industrial use. Universities have developed research focused on studying the technical feasibility of using these recyclable materials as an alternative for the construction of environmentally friendly structural elements [17]. Ghernouti and Bahia incorporate plastic bag waste as a fine aggregate in Mortar and study the mechanical properties and durability of mortar in comparison to control mortar. They concluded that incorporating plastic bag wastes in mortar reduce the compressive strength of the mortar by 1820% of the reference mortar. The replacement of sand by plastic bag wastes improved mortar behavior in acidic medium and its sensitivity to cracking [18]. [19] used plastic bags (PVC) as a construction material as an aggregate in concrete and concluded that the use of these materials in concrete reduces its compressive strength and increase its tensile capacity up to ambient limit. [20] studied the behavior of mortar by use of PVC as an aggregate in three different percentages and concluded that using PVC aggregate leads to worse performance in some properties. However, the modified mortars show a significant improvement in comparison to control mortar.

3 METHODOLOGY

Plastic waste was collected for money at the production site. Other materials like sand, cement and water were made readily available. Aggregation of the plastic was carried out. Plate 1 shows the Aggregation of Plastic Waste. The following plastic to sand ratios were selected and the concrete block produced and cured.

- 10% Plastic-90% Sand
- 20% Plastic-80% Sand
- 30% Plastic-70% Sand
- 40% Plastic-60% Sand
- 50% Plastic-50% Sand



Plate 1. Aggregation of Plastic Waste

3.1 Water absorption test

In this the block first weighted in dry condition and they are immersed in water for 24 hours. After that they are taken out from water and they are wiped out with cloth. Plate 2 shows the Shredded Plastics while plate 3 shows the curing of Plastics - Sand Block. Then the difference between the dry and wet bricks percentage are calculated using the formula below as used by;

$$\text{Water absorption (\%)} = \left[\frac{W_w - W_d}{W_w} \right] \times 100\% \quad (1)$$

where: W_w = Wet weight of specimen [g]; W_d = Dry weight of specimen [g].



Plate 2. Shredded Plastics



Plate 3. Curing of Plastics - Sand Block

3.2 Compressive Test

This is done to know the compressive strength of the concrete blocks. This is also called crushing strength of blocks. Generally, three specimens each of the concretes produced were taken to laboratory for testing and tested one by one. In this test a block specimen is put on crushing machine and applied pressure till it breaks. The ultimate pressure at which block is crushed is taken into account. All the specimens are tested one by one and average result is taken as block's compressive/crushing strength. The plastic sand of different ratios is tested one by one and in this the high compression is found and comparison made with the normal bricks. Plate 4 shows the Compressive Test using Compressive Test, Machine Seidner SWP200EMI Model.



Plate 4. Compressive Test using Compressive Test Machine Seidner SWP200EMI Model

4 RESULTS AND DISCUSSION

4.1 Water Absorption Test

Table 1 shows all the sample blocks produced from plastic aggregates have water absorption (WA) values ranging from between 1.70% to 2.04%. All these values are abysmally lower than the WA 17.70% value of the cement block. This means disintegration of the cement blocks by alternate wetting and drying is more likely than in the plastic derived blocks. The lower WA recorded by the plastic derived blocks give them an edge in terms of efficiency and durability especially in waterlogged areas. This result is in agreement with [21, 22]. The difference between weights of cubes in wet and dry condition is the water absorbed by the specimens. The moisture absorption is then expressed in percentage of water absorption. The less water absorbed by block, the greater its quality. Good quality block doesn't absorb more than 20% water of its own weight [22].

Table 1. Water absorption test of the samples.

Samples (Plastics - Sand)	Water Absorption (%)
Control	17.7
10 – 90	2.04
20 – 80	1.87
30 – 70	1.83
40 – 60	1.8
50 – 50	1.7

4.2 Compressive Strength Test

Table 2 shows the result for the compressive strength of the different samples represented. The Compression test shows that the control sample has the highest compressive strength of 13.2N/mm², a value which is almost twice the value of the plastic derived blocks. However, other

mix ratios equally have their degrees of variation. From the table above, 2.0 N/mm² is the minimum strength observed, but 10 and 20% plastic and sand ratio are more preferable due to their strength. This result is in agreement with [21, 22].

Table 2. Results of Compressive Strength of Samples

Plastic/sand Ratio	Age (days)	Concrete grade	Weight (gm)	Density (g/cm ³)	Dial reading (kn)	Strength (n/mm ²)	Remarks
Control	5	1:03	7649	2.26	298	13.2	Ok
10/90	5	1:03	6715	1.98	147	6.4	Ok
20/80	5	1:03	6345	1.87	90	4	Ok
30/70	5	1:03	5627	1.66	45	2	Ok
40/60	5	1:03	4030	1.2	6.8	0.3	Fail
50/50	5	1:03	3202	0.94	Nil	0	Fail

5 CONCLUSIONS

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 using cement alone. The Plastic sand blocks possess more advantages which include Cost efficiency, Removal of waste products thus abolishing the land requirement problem for dumping plastic. Based on the outcome of the results of the various tests carried out, the study has clearly established that the plastic derived blocks can be used in the stead of the blocks produced from conventional cement. The 30 to 70%, 40 to 60% and 50 to 50% Plastics to Sand block produced can be used in swampy domiciliary as interlock where heavy moving vehicles don't trample.

REFERENCES

1. Papari, S., Bamdad, H. and Berruti, F. (2021). Pyrolytic Conversion of Plastic Waste to Value-Added Products and Fuels: A Review. *Materials*, vol. 14, pp. 1-16. 2586. <https://doi.org/10.3390/ma14102586>.
2. Moharam, R. and Maqtari, M.A.A. (2014). The impact of plastic bags on the environment: A field survey of the City of Sana'a and the surrounding Areas, Yemen. *Int. J. Eng. Res. Rev.*, vol. 2, pp. 61-69.
3. Amit Gawande, G.Z., Renge, V.C., Saurabh, T. and Bharsakale, G. (2012). An overview on waste plastic utilization in asphaltting of roads. *Journal of Engineering Research and Studies (JERS)*, vol. 3, Issue 2, pp. 1-5.
4. Naseer, A. (2009). Performance behavior of confined brick masonry buildings under seismic demand (Doctoral dissertation, NW. FP University of Engineering and Technology, Peshawar, Pakistan), pp. 6-10.
5. Youcef, A.S. and Ganesh, M.N. (2015). Use of Recycled Plastic bag Waste in the Production of Concrete. *Journal of International Scientific Publications, Materials, Methods and Technologies*, vol. 8, no. 3, pp. 1314-7269.
6. Joel, S. and Ravikant, T. (2015). Manufacture of Interlocking Concrete Paving Blocks with Fly Ash and Glass Powder. *International Journal of Civil Engineering and Technology*, vol. 6, no. 4, pp. 55-64.
7. Shanmugavalli, B., Gowtham, K., Nalwin, P.J. and Moorthy, B.E. (2017). Reuse of Plastic Waste in Paver Blocks. *International Journal of Engineering Research and Technology (IJERT)*, vol. 6, no. 2, pp. 312-315.

8. Dinesh, S., Dinesh, A. and Kirubakaran, K. (2016). Utilisation of Waste Plastic in Manufacturing of Bricks and Paver Blocks. *International Journal of Applied Engineering Research*, vol. 11, no. 3, pp. 364-368.
9. Ganesh, T., Satish, P., Pramod, P. and Hemraj, R.K. (2014). Recycled Plastic used in Concrete Paver Block. *International Journal of Research in Engineering and Technology*, vol. 3, no. 9, pp. 2319-2323.
10. Jain, P.K., Shanta, K. and Sengupta, J.B. (2011). Mitigation of Rutting in Bituminous Roads by use of Waste Polymeric Packaging Materials. *Indian Journal of Engineering and Materials Sciences*, vol. 18, no. 1, pp. 233-238.
11. Lajeunesse, S. (2004). Plastic bags are not created equal because they are meant for different purposes September 20, 2004, vol. 82, no. 38, pp. 51-56. <http://pubs.acs.org/cen/whatstuff/stuff/8238plasticbags.html>.
12. Rößler, C. and Bui, D. (2014). Pozzolanic reactivity of mesoporous amorphous rice husk ash in portlandite solution. *Construction and Building Materials*, vol. 59, pp. 111-119. Available at: <https://doi.org/10.1016/j.conbuildmat.2014.02.046>.
13. Amadi, A.N., Nwankwoala, H.O., Eze, C.J., Alkali, Y.B. and Waziri, S.H. (2012). A Review of Waste Management Techniques in Parts of Niger Delta, Nigeria. *Centre for Human Settlement and Urban Development Journal*, vol. 3, no. 1, pp. 98-108.
14. Reddy, C., Chandra Kumar, B. and Asadi, S. (2019). Utilization of low density polyethylene waste in the manufacturing of paver brick. *International Journal of Recent Technology and Engineering*, vol. 7, Issue 6C2, pp. 62-67.
15. Constantin, J., Shitote, S., Abiero Gariy, Z. and Ronoh, E. (2019). Influence of coarse aggregate on the physical and mechanical performance of paving blocks made using waste plastic. *International Journal of Engineering Research and Technology*, vol. 12, Issue 6, pp. 912-916.
16. Tulashie, S., Boadu, E., Kotoka, F. and Mensah, D. (2020). Plastic wastes to pavement blocks: A significant alternative way to reducing plastic wastes generation and accumulation in Ghana. *Construction and Building Materials*, vol. 241, pp. 2-4.
17. Serano, G. and Perez, R. (2011). Architect's and Geologist's View on the Causes of Building Failures in Nigeria. *Modern Applied Science*, vol. 6, no. 6, pp. 31-38. DOI: 10.5539/masv6n6p31.
18. Ghernouti, Y. and Rabehi, B. (2012). Strength and Durability of Mortar Made with Plastics Bag Waste. *International Journal of Concrete Structures and Materials*, vol. 6, pp. 145-153. DOI: <https://doi.org/10.1007/s40069-012-0013-0>.
19. Glaoui, B. (2015). Plastic Waste in Cement Concrete, LDPE and PVC introduction effect. In *Advanced Materials Research. Trans Tech Publications*, vol. 1105, pp. 325-330. DOI: <https://doi.org/10.4028/www.scientific.net/AMR.1105.325>.
20. Da Silva, A.M., De Brito, J. and Veiga, R. (2014). Incorporation of fine plastic aggregates in rendering mortars. *Construction and Building Materials*, vol. 71, pp. 226-236. DOI: 10.1016/j.conbuildmat.2014.08.026.
21. Owolabi, W. and Amadi, A.N. (2020). Production of Pavement Blocks from Plastic Waste. *The Pacific Journal of Science and Technology*, vol. 2, pp. 36-43.
22. Murad, A., Naveed, I., Saddeq, U., Mohammed, R. and Muhammed, A. (2020). Mechanical Properties of Polyethylene-Sand Blocks Produced from Recycled Plastic Bags. *International Journal of Scientific and Engineering Research*, vol. 11, Issue 1, pp. 1278-1283.