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Investigation of the Compressive Strength of Sand-Filled Polyethylene Terephthalate Bottles as a Material for Wall Construction

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The disposal of plastic wastes in the environment has negatively impacted the environment as plastics are non-biodegradable and contain chemicals that are harmful to humans, animals, plants, and the environment at large. The increased demand for infrastructure across the globe has also resulted in a rapid depletion of natural resources used for the production of construction materials. The need therefore arises for research to proffer solutions that would lead to the better management of plastic wastes, and provide sustainable construction materials. This study evaluated the compressive strength of sand-filled PET bottles (with varying moisture content, 0-

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15%) and clay bricks incorporating sand-filled PET bottles for wall construction. Cement was used to stabilize the clay at 0%, 10%, and 15% by weight. The compressive strength of the bricks produced was compared with that of control bricks (without sand-filled PET bottles). The results obtained reveal that the compressive strengths of the PET bricks were less than those of the control bricks. An optimum of 2% moisture content of sand is recommended for filling the PET bottles while 15% stabilization of clay with cement is recommended for the production of sand-filled PET bricks. The sand-filled PET bricks can be used for non-load-bearing wall construction as their compressive strengths fall below the minimum requirements of the Nigeria Building and Road Research Institute and the Standards Organization of Nigeria for load-bearing walls.

Keywords: Polyethylene terephthalate; waste management; infrastructure; compressive strength.

1. INTRODUCTION

The surge in global population has led to an exponential demand for infrastructure. This has resulted in a rapid depletion of natural resources used for the production of construction materials. Also, the ever-rising costs of construction materials have led to increased costs of infrastructural development, making it a herculean task for low-income earners to build decent houses. To meet this demand, research in recent years has focused on the use of indigenous, traditional, and waste materials such as PET bottles, as a constituent material in construction processes [1-2].

The availability of natural aggregates and construction materials is gradually dwindling and have become more expensive due to its increased demand. The depletion of natural reserves of materials used in the construction industry and the disposal of wastes in the environment has been of global concern in the last few decades due to the environmental impact arising from these activities. Poor waste management usually has adverse effects on humans, animals, plants, soil, and the environment. Global warming, for example, is primarily caused by human activities that release harmful wastes (gases) into the environment. In recent years, plastic waste has made up a bulk of municipal solid waste in cities around the world. Plastic constitutes about 50% of about 300 million tonnes of global waste generated in 2015 [1,3].

Plastic waste disposal is a global concern since it is nonbiodegradable in nature and hazardous, because of its potentially harmful effect on human health and the environment. The enormous amounts of plastic waste bring disastrous consequences, such as pollution (i.e., air, land, marine), food chain contamination, biodiversity breakdowns, energy waste, and economic loss. Every year not less than 200 billion bottles of bottled water are consumed globally. Only about 15% of this quantity is recycled in all recycling plants across the globe while the remaining ones end up in trash bins, landfills, or open dumpsites in cities across the globe [4,5]. Plastic bottles make up about 11% of the contents of landfills [6]. An effective waste management system is therefore necessary for economic growth, the overall well-being of mankind, and environmental sustainability.

Plastic has different properties such as durability and corrosion resistance, good isolation for cold, heat, and sound, saving energy, economical, longer life span, and lightweight. Because of their lower cost, higher flexibility, manufacturing ease, high strength, thermal stability and transparency, and better performance, plastics are replacing the conventional materials like metal, wood, and glass, used in the food and beverages industry. Polyethylene Terephthalate (PET) is one of the most common plastic products used for packaging food and beverages [2-10].

The utilization of plastic wastes such as PET for construction purposes will help mitigate the environmental issues arising from the disposal of plastics in the environment and the depletion of natural resources used to produce construction materials, resulting in more sustainable environmental practices.

Rahman et al. [11] investigated the suitability of the use of air-filled PET bottles for cavity wall construction. Their findings showed that the blocks produced performed satisfactorily as they met the required compressive strength for blocks used for cavity wall construction. They also observed a 27% reduction in the material cost when air-filled PET bottle blocks were used as compared to the traditional hollow concrete blocks.

Afolayan et al. [2] carried out a study to evaluate the compressive and flexural strengths of bricks made using laterite-filled PET bottles. The laterite-filled PET bottles were embedded in cement-stabilized clay. The results obtained reveal that the blocks produced with 15% cement-stabilized clay had the highest compressive strength. They recommended that the bricks produced to be used for the construction of non-load-bearing walls.

Chaurasia & Gangwar [6] used PET bottles filled with soil to construct a toilet and a hanging garden. They observed that the use of PET bottles instead of bricks for wall construction had a substantial effect on saving the building embodied energy and reduced the CO_2 emission associated with the use of cement.

Sharma [8] observed that PET bottles filled with well-compacted sand, soil, fly ash, and plastic wastes can be used as a building material replacing traditional bricks as the strength parameters of filled plastic bottles are on a higher end as compared to traditional bricks. It was further observed that bricks made using filled PET bottles are lighter in weight and possess the same thermal properties as traditional bricks. They also have a high sound reduction index as compared to concrete blocks and do not permit light to pass through them as when seen by the naked eye.

Tokpomehoun et al. [12] evaluated the structural performance of blocks incorporating PET bottles filled with different soil types (red coffee, murram, and black cotton) bonded with cement mortar for wall construction. The test results reveal that the compressive strength of all the blocks produced was higher than the minimum requirement for masonry units in Kenya. The blocks produced having PET bottles filled with murram soil performed better than the others with a compressive strength of 2.8Mpa.

The current research aims to investigate the compressive properties of the sand-filled PET bottles and bricks incorporating sand-filled PET using clay stabilized with cement (0%, 10%, and 15%) as a binder for the construction of walls.

2. MATERIALS AND METHODS

The materials and methodology employed in this study are presented as follows

2.1 Materials

The materials used for this study are as follows

2.1.1 PET bottles

The PET Bottles (500ml) used were obtained from waste collection points, retail shops, and event centres in Ibadan, Nigeria. Bottles in good shape and condition were sorted, washed, and dried after collection, and were used for this study (see Fig. 1). The failure load of the empty PET bottle is 1.5kN.

2.1.2 Cement

Ordinary Portland Cement Grade 32.5 purchased in Ibadan, Nigeria, conforming to the requirements of NIS 444-1: 2003 [13] was used for this research.

2.1.3 Clay

Brown coloured clay conforming to the requirements of BS EN 12620 [14] was used for this research. It was sourced from Ibadan environs, Ibadan, Nigeria. The clay was sun-dried for 7 days to remove moisture in it and sieved using a 4.75mm sieve. The clay has a natural moisture content of 15.2%, a bulk density of $1.21g/cm^{3,}$ and a specific gravity of 1.82.

Fig. 1. PET bottles used

2.1.4 Fine aggregate

Sharp river quartzite sand free of clay, loam, dirt, and any organic or chemical matter, and a maximum size of 4.75mm sourced from a stream inside the University of Ibadan Campus, Ibadan, Nigeria was used for this study. It has a specific gravity of 2.62, a bulk density of 1.81g/cm^{3,} and a fineness modulus of 2.75. The sand was sun-dried for 7 days before its use.

2.1.5 Water

Potable tap water was used for this study.

2.2 Experimental Investigation

2.2.1 Specimen preparation

Firstly, 21 PET bottles comprising empty and sand-filled (with 0%, 2.5%, 5%, 7.5%, 10% and 15% moisture content) bottles were tested for their compressive strengths. This was done to ascertain the optimum moisture content of the sand to be used to fill the bottles. The PET bottles were filled with sand in 3 layers with the aid of a filter funnel. Each layer was given 20 blows with the aid of a tamping rod. Moisture was added to the sand to increase its density.

To produce the PET bricks, sand containing the optimum moisture content was poured into the bottles in 3 layers, having each layer with 20 blows using a tamping rod. Bricks measuring 260mm x 160mm x160mm (this size is adapted from the research by Afolayan et al. [2] were cast using a mixture of clay and cement as the binder, with a water-to-binder ratio of 0.30. Cement was used to partially replace clay at 0%, 10%, and 15% replacement by weight. The sand-filled bottles were horizontally arranged in the bricks after which they were cast with thoroughly mixed clay-cement mortar. Control specimens (without PET bottles) were also cast. 18 bricks were cast, comprising 9 control (without PET bottles) bricks and 9 sand-filled PET bottle bricks. Mixing and casting of the specimen was done manually. The bricks cast were extruded from the moulds after 24 hours and placed in a water bath to cure for 28 days, after which they were tested for their compressive strength.

Casting, compaction, and curing of the specimens were conducted in accordance with B.S. EN 12390-parts 1 and 2 [15-16] while compressive strength tests were carried out in accordance with B.S. EN 12390-3 [17]. Fig. 2a and 2b show a sand-filled bottle and a PET brick specimen respectively being tested. The tests were carried out at the Materials Testing Laboratory, Department of Civil Engineering, University of Ibadan, Nigeria.

3. RESULTS AND DISCUSSION

3.1 Compressive Strength of Filled PET Bottles

The results for the compressive strength tests on the sand-filled (with 0%, 2.5%, 5%, 7.5%, 10%, and 15% moisture content) PET bottles are presented in Fig. 3. The results obtained indicate

(a) (b)

Fig. 2. Compressive strength test (a) empty PET bottle (b) PET brick

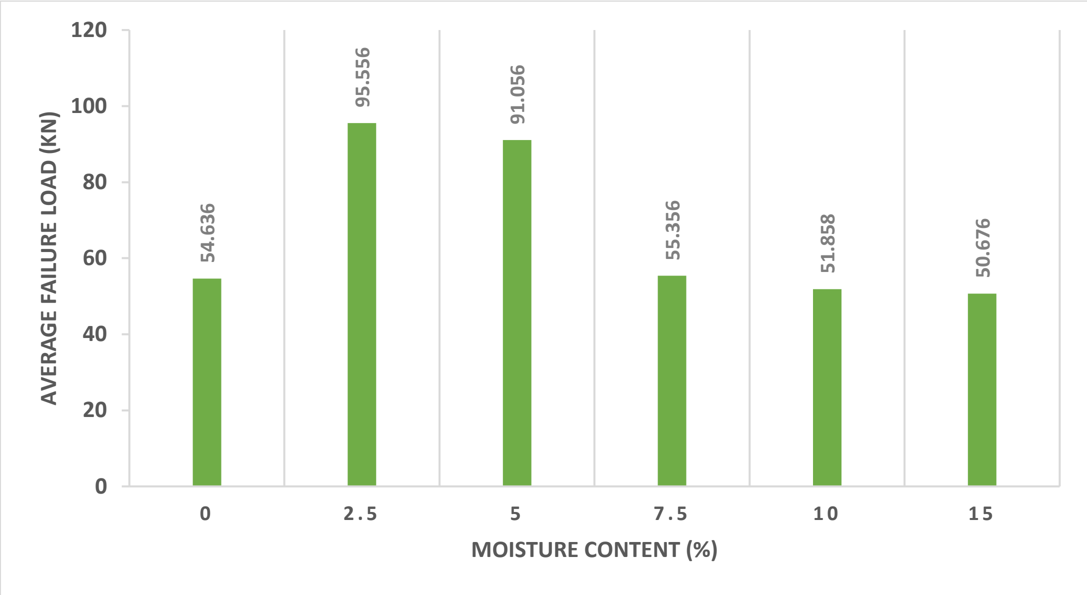

Fig. 3. Graph showing the average failure load of sand-filled PET bottles

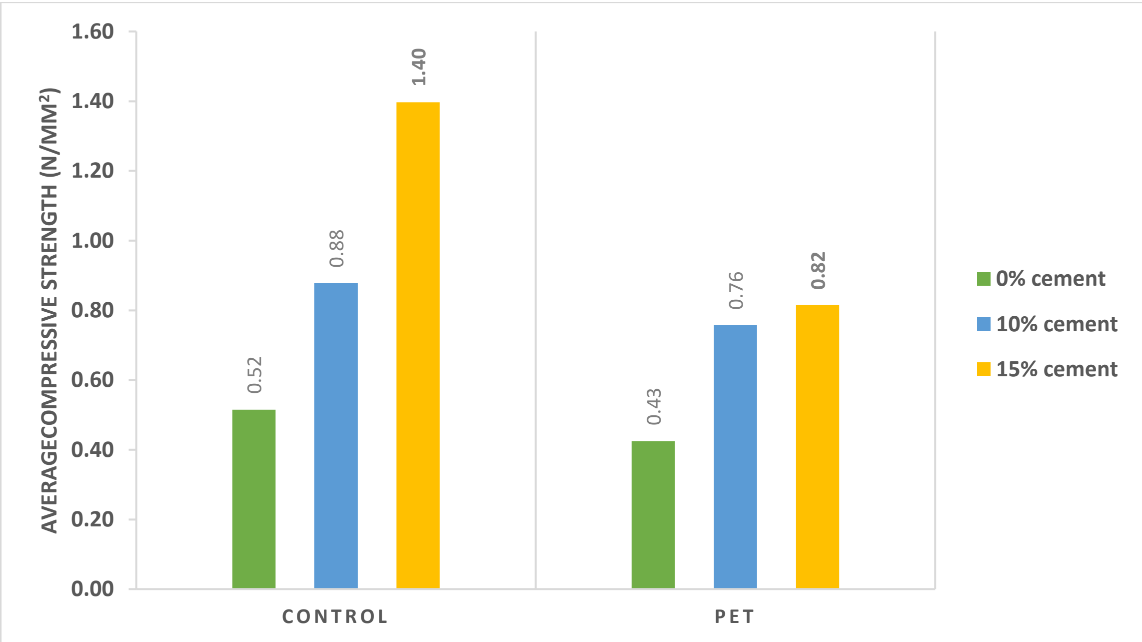

Fig. 4. Graph showing the average compressive strength of the bricks

that the compressive strength of the specimen increased as the moisture content increased up to 2.5%, beyond this moisture content, the compressive strength kept declining. The decrease in compressive strength of the specimen can be attributed to the reduced cohesion between sand particles as the moisture content increases. An optimum moisture content of 4% was obtained in the investigation by Afolayan et al. [2].

3.2 Compressive Strength of Sand-Filled PET Bricks

The results of the compressive strength tests on the bricks are presented in Fig. 4. From the results obtained, it was observed that the compressive strength of all the bricks increased as the quantity of cement increased. It was also observed that the bricks with sand-filled PET bottles had lesser compressive strength when compared with the corresponding control bricks (without PET bottles). There was a 21.18%, 15.98%, and 71.41% difference between the compressive strengths obtained for the control and PET bricks with 0%, 10%, and 15% respectively in the cement content of the binder. A similar trend was observed in the study carried out by Afolayan et al. [2]. The increase in the compressive strength of the bricks as the cement content increases can be attributed to the stabilizing effect of cement in the matrix.

The value of the compressive strength falls below the minimum requirement of 1.65N/mm^2 for load-bearing earth blocks and 2.5N/mm^2 for load-bearing sandcrete blocks as specified by the Nigeria Building and Road Research Institute [18] and the Standards Organization of Nigeria [19] respectively.

4. CONCLUSION

The study investigated the compressive strength of sand-filled PET bottles (with varying moisture content of 0-15%). Clay bricks incorporating sand-filled PET bottles with varying cement content (0%, 10%, and 15%) were also produced and tested for their compressive strengths. The compressive strength values of the bricks were compared with those of control bricks (without PET bottles) to ascertain their suitability as wall construction materials. An optimum of 2% moisture content was obtained for sand-filled PET bottles. The results also reveal that the compressive strength of sand-filled PET bottle bricks was less than that of the control bricks. 15% stabilization of clay with cement is recommended for the production of sand-filled PET bricks.

From the study, it can be concluded that the use of PET bottles is an environmentally friendly material construction and its use will promote the profitable utilization of waste materials. Also, sand-filled PET bricks can be used for the construction of non-load-bearing walls as their compressive strengths fall below the minimum requirements of the Nigeria Building and Road Research Institute [18] and the Standards Organization of Nigeria [19] for load-bearing walls.

Further research can be carried out to evaluate other strength properties, thermal properties, and durability of sand-filled PET bricks.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Onugba MA, Omisande LA, Alhassan YA, Abdullahi AO, Enhancing earth-based building materials: effect of palm fibre reinforcement on compressive strength. Journal of Engineering Research and Reports. 2023;25(11):55-63. Available:https://doi.org/10.9734/JERR/2023/v25i11020
2. Afolayan OD, Salawu AM, Dahunsi BI, Odetoyan AO, Akpabot AI, An evaluation of compressive and flexural properties of laterite filled pet bottles as a wall construction material. International Journal of Civil Engineering and Technology. 2018; 9(8):1783-1792
3. Dadzie DK, Kaliluthin AK, Kumar DR, Exploration of waste plastic bottles use in construction. Civil Engineering Journal. 2020;6(11):2262-2272. Available:http://dx.doi.org/10.28991/cej-2020-03091616
4. Haque MS, Sustainable use of plastic brick from waste PET plastic bottle as building block in Rohingya refugee camp: a review. Environmental Science and Pollution Research; 2019. Available:https://doi.org/10.1007/s11356-019-06843-y
5. Abdulkarim IA, Abiodun AO, A study of problems associated with pet bottles generation and disposal in Kano metropolis. Academic Research International. 2012;3(2):56-65
6. Chaurasia A, Gangwar S, Reuse of plastic bottles as a construction material. International Journal of Engineering and Technical Research. 2019;9(9):25-30
7. Choudhary K, Sangwan KS, Goyal D, Environment and economic impacts assessment of PET waste recycling with conventional and renewable sources of energy. Procedia CIRP. 2019;80(422–427). Available:https://doi.org/10.1016/j.procir.2019.01.096
8. Sharma H, Innovative and sustainable application of pet bottle a green construction overview. Indian Journal of Science and Technology. 2017;10(16):1-6.

Available:https://doi.org/10.17485/ijst/2017/v10i16/114307
9. Anil A, Devika AS, Alexander E, Bhavanikutty M, George A, Polyethylene terephthalate (PET) bottle construction. International Journal of Engineering Research & Technology. 2016;4(13): 1-3.
10. Bello ZA, Use of campus plastic pet (polyethylene terephthalate) bottles in the construction of a mini student relaxation hub at the college of education, Ilorin: A waste-to-wealth reusing approach. International Journal of Natural Science Research. 2023;11(1):24-33. Available:https://doi.org/10.18488/63.v11i1.3328
11. Rahman T, Islam GMS, Aich P, Das KK, Sultana Z, Development of recycled air-filled PET bottle blocks for cavity wall construction. International Journal of Scientific Research in Engineering and Management. 2023;7(8):1-4.
12. Tokpomehous GM, Oyawa WO, Nganga TJ, Okumu VA, Structural performance of plastic block masonry unit. Heliyon. 2022; 8(12):E11112. Available:https://doi.org/10.1016/j.heliyon.2022.e11112
13. Standards Organization of Nigeria. NIS 444-1: Cement – part 1: Composition, specification and conformity criteria for common cements. SON, Abuja, Nigeria; 2003.
14. British Standards Institution. Aggregates for concrete; 2002.
15. British Standards Institution. Testing of hardened concrete – part 1: Shape, dimensions and other requirements for specimens and mould. 2000;12390:1.
16. British Standards Institution. Testing of hardened concrete – part 2: Making and curing specimens for strength tests. 2000;12390:2.
17. British Standards Institution. Testing of hardened concrete – part 3: Compressive strength of test specimens. 2002;12390:3.
18. Nigeria Building and Road Research Institute. NBRRI interlocking block making machine. NBRRI Newsletter. 2006;1(1): 15-17.
19. Standards Organization of Nigeria. NIS 87: Standard for sandcrete blocks. SON, Abuja, Nigeria; 2004.

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