Sustainability in Environment
ISSN 2470-637X (Print) ISSN 2470-6388 (Online)
Vol. 8, No. 3, 2023
www.scholink.org/ojs/index.php/se

Original Paper

Evaluation of Bottle Bricks Walls Using Polyethylene Terephthalate (pet) Bottle as Bricks

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Received: May 22, 2023 Accepted: July 13, 2023 Online Published: July 19, 2023

doi:10.22158/se.v8n3p50 URL: http://dx.doi.org/10.22158/se.v8n3p50

Abstract

There has been a considerable imbalance between the availability of conventional building materials and their demand in the recent past. On the other hand, the plastic waste is abundantly available and the disposal of waste Polyethylene Terephthalate Plastics (PET) is a big challenge, as repeated recycling of PET bottles poses a potential danger of being transformed and only a small proportion of PET bottles are being recycled. In this work an attempt has been made to access material for building walls in term of using pet bottles bricks in respect to using different filer material and test their suitability and also experimenting their compressive strength. This research identifies the various suitable materials for making bottles brick and make use of reviewed paper, relevant literature, archival data and material inspection as a method of study. The solution to finding the physical properties of bottle brick was carried out through collecting data and information through scrutinize material inspection and literature reviewing. This research concerns with subjective assessment of attitudes, qualities and behaviour of different material filled in PET bottles for making PET bottle brick walls. Also these suitable samples were collected and analyzed by experimenting the compressive strength of each of material filled in each PET bottle. At the end, it concluded that different factor affects the use of suitable filler such as availability of the material, cost of material among others. PET bottle brick has advantages such as high strength, low cost, load capacity, reducing waste and energy efficiency, PET bottle bricks can be more effective compared to some conventional wall building materials such as brick, sandcrete block and ceramic block.

Keywords

Building Construction, Bottle bricks, Compressive strength, Recycled Materials, Waste Pet bottle

1. Introduction

The idea of utilizing plastic bottles in concrete building construction was originally conceived by Eco-Tec Environmental Solutions to help deal with global warming and to create less waste in the environment (Andreas Froese, 2014). Eco-Tec began using the bottles as a solution to the problem of garbage disposal that was asked by Andreas Froese with an innovative solution, Eco-Tec's primary activities include advising and training in green building, eco-design, composting, and vermiculture (Andreas Froese, 2014).

One of the main disadvantages in constructing world house is high cost of buildings. High cost of primary requirements for constructing the houses in places where people are under poverty line, is forming one of the most significant problems of people. On the other hand, urbanization growth will increase rubbish especially non-renewable ones. A suitable approach for this situation is using some part of urban rubbish as required materials for building construction and also providing comfortable situation and suitable thermal comfort for building residents (Shoubi et al., 2013).

Brick is defined as a building material used to make walls, pavements and other elements in masonry construction. Traditionally, the term brick refers to a unit composed of clay, but it is now used to denote any rectangular units lay in mortar. A brick can be composed of clay-bearing soil, sand and lime, or concrete materials. Bricks are produced in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities (Alvarado, 2010).

The plastic industry is one of the fastest growing industries around the world with almost one trillion plastic bags covered per year is being used and it is just one example of product of plastic. Simon Jose and Balasubramanian, 2014 explained that plastic is one of the recent engineering materials which have appeared in the market all over the world, there has been a step rise in the production of plastics for years now; it touches around 1000 million in 2014. Because Plastics are normally stable and not biodegradable their disposal poses a problem (Simon & Balasubramanian, 2014).

Polyethylene terephthalate (PET) is used as a raw material for making packaging materials such as bottles and containers for packaging a wide range of food products and other consumer goods (Irwan, et al., 2013). Examples include soft drinks, alcoholic beverages, detergents, cosmetics, pharmaceutical products and edible oils. PET is one of the most common consumer plastics used in Nigeria which are used to package popular table water, beverages in the country.

Across Nigerians cities and villages, as in many other developing countries, solid waste, including PET bottles and other non-biodegradable materials, end up at dump sites and landfills, often clogging drains and waterways, contributing to health and environmental hazards, as such PET domestic waste are causing considerable damage to the environment and hence an attempt is been made to understand whether they can be successfully used as a walling material.

The consumption of plastic has grown substantially all over the world in recent years and this has created huge quantities of plastic-based waste. Plastic waste is now a serious environmental threat to the modern way of living. Waste plastic bottles are major reason of solid waste disposal, as cited by

(Abah, 2015), 78% of hazardous wastes in Nigeria are plastics, many of the harmful chemicals associated with plastics poses serious health risks to man and other living things around. Polyethylene Terephthalate (PET) bottles are usually used for packaging carbonated beverage and water. Plastics consumption nowadays have become an integral part of our lives. The amounts of plastics consumed annually have been increasing steadily. There are several factors that contribute to the rapidly growth of plastics consumption such as low density, fabrication capabilities, long life, lightweight, and low cost of production (Siddique et al., 2007). Plastic has been used widely in packaging, automotive and industrial applications, medical delivery systems, artificial implants, other healthcare applications, land/soil conservation, water desalination, flood prevention, preservation and distribution of food, housing, communication materials, security systems, and other uses. Large applications of plastics in all part of daily activities increase the volume of plastic waste (Irwan et al., 2013).

According to Iucolano et al., 2013 the annual plastic consumption in Western Europe is approximately 60 million tonnes out of which 23 million tonnes end up as plastic wastes and in India, demand for plastic bottles between 2005 and 2006 was approximately 20 trillion (Silva et al., 2013). Worldwide, plastic products contribute substantially to an ever increasing volume of Municipal Solid Waste (MSW) streams. Globally, it constitutes 7-9% of MSW, 15-25% in Europe (Panda et al., 2010), 7% in UK (Parfitt, 2002) and 2% in Lagos State, Nigeria (Longe, 2004). According to USEPA, 2008 and MSW, 2002, In US, the highest tonnage in plastic MSW is containers and plastic packages. Also Clarke and hardy elaborated that in Europe; packaging represents 37.2% of all plastics consumed and 35% worldwide.

Plastic waste cannot be dumped in landfills because of its bulk and slow degradation rate, it is a stable and non-biogradable material making its disposal and recycling an issue of consideration. The use of plastic waste as a material in construction would be good way of addressing this issue, the use of plastic in producing pet bottle bricks wall given its economic and ecological advantages is also a considerable fact (Saikiaa & Britoa, 2013).

PET is used for high impact resistant container for packaging of soda, edible oils and Peanut butter. It is also used for cereal box liners, microwave food trays as well as in medicine for plastic vessels and for Implantation. Plastic is heat resistant and chemically stable. PET bottle is resistant to acid, base, some solvents, oils, fats. PET bottles are also difficult to melt (Aditya et al., 2015).

2. Materials and Equipment for Research

2.1 Collection of Materials

Plastic bottle of about 750 ml were collected from the dump site at the Federal University of Technology, Akure and delivered to the Department of Building workshop. The materials collected were pet bottles, sand, inorganic waste (trash), granite, stone-dust and clay soil.

2.2 Fillers

The sand, stone dust and granite used are gotten from the building workshop where the experiment was carried out. Clay used were obtained from the site of newly constructed road along FUTA campus road and the trash was from domestic dustbin containing wrap sheets of used products of food among others.

2.3 Equipment

The materials used for the research are, Plastic bottle, shovel for packing materials; Head pan for packing and transporting materials; Tampering rod for compacting the material; Compression testing machine to crush each sample in order to determine the peak load and sample stress, Weighing balance to measure the weight of each sample.

2.4 Preparation of Samples

The Plastic bottles were sun dried to remove water, the bottles were filled with the soil samples and compacted with wooden spoon. The available materials was screened by a sieve shaker properly so as to remove any unwanted foreign large size particles They are tightly capped and sealed. Various test was performed to check the structural strength of the samples.

2.5 Laboratory Analysis of Samples

To ensure that the selected samples used for this research work comply with established standards, compressive strength test and analysis was carried out on each samples in the following order as shown in the figure below.

Sample 1. Pet bottles +Sand, Sample 2. Pet bottles + Stone-dust, Sample 3. Pet bottles + Granite, Sample 4. Pet bottles + Clay, Sample 5. Pet bottles + Trash

Figure 1. Pet Bottle + Sand

Figure 2. Pet Bottle + Stone Dust

Figure 3. Pet bottle + Granite

Figure 4. Pet bottle + Clay

Figure 5. Pet Bottle + Trash

2.6 Procedures

The samples were prepared in three replicates for each sample, weighed and the crushing load was determined on a compressive strength testing machine.

3. Compressive Strength Test Machine

ADR Touch 2000 BS EN Compression Machine with Digital Readout and Self Centering Platens available in the workshop of Department of Building was used. The computer controlled hydraulic

compression testing machine consists of load frame; The load frame is a welded steel fabrication carrying the ball-seated upper platen. Positively located on the loading ram, which is protected from debris by a flexible cover, the lower platen is marked for the centering of the specimens.

3.1 Compressive Strength

Compressive strength was carried out to determine the strength of 250ml bottle brick. 0.75 litre each of Pet bottles +Sand, Pet bottles + Stone-dust, Pet bottles + Granite, Pet bottles + Clay, and Pet bottles + Trash using compression testing machine. From the testing, the maximum force applied on 250ml bottle until failure was determined

A total of 15 bottles of 250 ml bottles are used to produce bottle bricks. All the bottles are dried before filling with sand. Filter funnel is used to ease the filling of sand into the bottle since the opening of bottle is undersized. Sand is wet partially so that it can be compacted easily and thus increasing the density of bottle bricks. Sand is compacted in three layers and each layer is compacted with 25 blows with tamping rod. In order to make sure all the bottles are completely compacted, quality check is carried out and those which are less compacted are improved.

4. Results and Discussion

The results of the study on the accessing the various suitable materials for making pet bottles brick walls, identifying and accessing the physical properties of pet bottle brick walls and accessing the compressive strength of pet bottle bricks as walling material are discussed.

4.1 Suitable Materials for Bottle Bricks

Materials used as filler for bottles bricks is unending, but affected by some factors like, availability of the material; cost of material.

This research work experimented five (5) different materials as fillers in pet bottle bricks walls which are; Sand; Stone-dust; Granite; Inorganic waste (trash) and Clay.

4.2 Sand

Sands are naturally occurring granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. It is the aggregate most of which passes through a 4.75mm BS sieve and contains only that much coarser material as is permitted by the specifications. Sand is generally considered to have a lower size limit of about 0.07mm. According to Mokhtar, et al., 2015; Saraswat, 2013 and Slater, et al., 2012**.** It is concluded that, the application of PET bottle bricks filled with sand as wall structure to replace bricks in construction industry is suitable.

4.3 Stone-Dust

These are Crushed Stone, rock layers quarried and processed through a crushing and screen plant to reduce to desired size and divide into desired size groupings. It is pulverized stone used in the construction of walkways or other stable surfaces. The dust is mixed with soil and compacted or used with gravel to fill spaces between irregular stones. Stone dust is a by-product of stone crushing operations. This have almost the same properties as sand, thus there are suitable for PET bottle brick walls construction.

4.4 Granite

Granite is a light-colored igneous rock with grains large enough to be visible with the unaided eye. It forms from the slow crystallization of magma below Earth's surface. Granite is composed mainly of quartz and feldspar with minor amounts of mica, amphiboles, and other minerals.

4.5 Clay

Clay is a fine-grained natural rock or soil material that combines one or more clay minerals with traces of metal oxides and organic matter. Clays are plastic due to their water content and become hard, brittle and non–plastic upon drying or firing. Clays are distinguished from other fine-grained soils by differences in size and mineralogy. Silts, which are fine-grained soils that do not include clay minerals, tend to have larger particle sizes than clays. There is, however, some overlap in particle size and other physical properties, and many naturally occurring deposits include both silts and clay.

4.6 Inorganic Waste (Trash)

Inorganic waste is waste consisting of materials that are difficult biodegradable so that destruction takes a very long time. Inorganic rubbish comes from non-renewable natural resources such as minerals and

petroleum, or from industrial processes. Some of this material was not found in nature such as plastic and aluminum. Some inorganic substances as a whole cannot be explained by nature, while others can only be described in a very long time, this type of waste are found at the household level, in the form of bottles, plastic bottles, plastic bags, and cans.

This are the materials tested for as fillers in bottles for bottle bricks, however the use of other material like sawdust might be considered for future researches.

4.7 Properties of Bottle Brick Walls

A wall should not just be an enclosure. It provides far more than just protection from the outside elements. An appropriate designed and constructed wall is a fundamental part of the home and has far reaching impact on the health of the occupant.

4.8 Strength

In creating bulletproof and fireproof housing it as being reported that there is a great advantage of using bottle brick with compacted sand as it is about 20 times stronger than bricks (Brailow, 2015). Due to the compaction of filling materials in each bottle, resistance of each bottle against the load is 20 times higher compared to brick (Aditya, 2015). PET bottle walls can bear up to 4.3 N/mm ^{2}when the bottles are filled with sand which is the weakest filling material as described by (Shilpi et al., 2013).

4.9 Thermal Insulation

Shilpi et al., 2013 explained that by utilizing of PET bottles bricks in construction using recycled materials, thermal comfort can be achieved in very low cost housing, benefit in residents for those who cannot afford to buy and operate heating and cooling systems, as plastic is non-biodegradable, toxic, highly resistant to heat and electricity and not recyclable in true sense. As concluded by Mokhtar, et al., 2015 the plastic bottle bricks have the capability to replace standard bricks in condition of thermal comfort Pet bottle bricks structure has the added advantage of being with the interior room maintaining a constant temperature of 18 degrees C (64 degrees F) which is good for tropical climate (Aditya, 2015).

5. Earthquake Resistance

The walls built by these bottles are lighter than the walls built by brick and block, and that makes these buildings to show a good response against earthquake (Aditya, 2015).

5.1 Availability

Material used for making PET bottle brick are readily available in the surrounding and cost less than the conventional material for building wall like the bricks and the sandcrete blocks which goes through some process in the cause of its production.

5.2 Cost

The cost of construction involved when using PET bottle which are readily available around since they causes nuisance is expectedly cheap. Aditya and Kansal, 2014; Shilpi and Monika, 2013 and Slater et al., 2012 reported that It is expected that by utilizing PET bottles bricks in construction, thermal

comfort and aesthetic can be achieved in very low cost housing. Shoubi et al., 2013 describes that constructing a house by PET bottles used for the walls, joist ceiling and concrete column offers us 45% diminution in the final cost. Shoubi**,** et al., 2013 further explained that Separation of various components of cost shows that the use of local manpower in making bottle panels can lead to cost reduction up to 75% compared to building the walls using the brick and concrete block.

5.3 Bulletproof

The walls built by these PET bottles are lighter than the walls built by brick and block, and that makes these buildings to show a good response against earthquake. Due to the compaction of filling materials in each bottle, resistance of each bottle against the load is 20 times higher compared to brick. And these compressed filling materials, makes the plastic bottle to be prevented from passing the shot that makes the building as a bulletproof shelter (Shoubi et al., 2013).

5.4 Compressive Strength Result

The compressive strength for different materials filled in bottles for making pet bottle bricks wall were tested using compressive strength testing machine. Three (3) samples of each material are made and the average of three test results is taken for more accurate results. The values of the compressive strength obtained are presented in Table below

Table 1. Compressive Strength of Sand Pet Bottle Brick

SAMPLE	WEIGHT (Kg)	PEAK VALUE(KN)
A	1.5	102.1
B	1.5	84.7
C	1.5	95.3
AVERAGE	1.5	94.03

Table 2. Compressive Strength of Stone Dust Pet Bottle Brick

SAMPLE	WEIGHT (Kg)	PEAK VALUE(KN)
A	1.45	82.9
B	1.45	85.3
C	1.45	128.1
AVERAGE	1.45	98.77

Table 3. Compressive Strength of Granite Pet Bottle Brick

SAMPLE	WEIGHT (Kg)	PEAK VALUE(KN)
A	1.20	83.1
B	1.20	88.6
C	1.25	105.5

AVERAGE	1.22	92.4

Table 4. Compressive Strength of Clay Pet Bottle Brick

SAMPLE	WEIGHT(Kg)	PEAK VALUE(KN)
A	1.45	53.9
B	1.5	51.6
C	1.5	54.6
Average	1.48	53.37

Table 5. Compressive Strength of Inorganic Waste Pet Bottle brick

SAMPLE	WEIGHT(Kg)	PEAK VALUE(KN)
A	0.30	79.0
B	0.40	27.6
C	0.40	81.6
Average	0.37	62.

6. Discussion of Findings

Materials used as filler for PET bottles bricks is unending, but affected by some factors like, availability of the material; cost of material, as literature as reviewed. This project presents sand; stone dust; granite; clay; and inorganic waste (trash) as suitable material for making Pet bottle brick walls. However emphasis is made on the use of sand and inorganic waste as most preferable of these materials has they are cheap and easily procured compare to the other materials considered

The use PET bottle bricks in construction provides tremendous benefit to the construction industry as well as the economy of a country as nuisance caused by this Pet bottles is eradicated, readily available material is used in cause of construction.

PET bottle bricks are also considered to have various beneficial properties which are; Good construction ability, Suitable thermal behavior, Earthquake resistance, Bulletproof, Low cost of construction, Good sound insulation and Green Construction.

The results from table 4.6 show that all material tested are eligible as filler for PET bottle brick walls however, stone dust -filled pet bottle bricks and sand-filled pet bottle brick have a high compressive strength of 19.45 N/ mm2 and 18.52 N/ mm2 which means they have high resistant to fail under load. Bottle - filled wall would be the best choice for our house design project.

7. Conclusion

This research has proven that sand, stone-dust, granite , clay and trash are good enough to withstand load when used as filler in pet bottle brick wall construction as sand pet bottle brick as a compressive

strength of 18.52 N/ mm2 , stone- dust pet bottle brick as a compressive strength of 19.45 N/ mm2 , granite pet bottle brick as a compressive strength of 18.20 N/ mm2 , clay pet bottle brick as a compressive strength of 10.51 N/ mm2 and in-organic waste pet bottle brick as a compressive strength of 12.36 N/ mm2 . But from economic considerations inorganic waste which is the most cheapest filler material and available and as a compressive strength 12.36 N/ mm2 that is far more greater than the minimum compressive strength for brick and sand-Crete block which is 3.0 N/ mm2 and 1.75 N/ mm2 respectively according to the Nigeria building code .The efficient usage of

in-organic waste in pet bottle bricks wall construction will result in the effective usage of plastic waste and trash and thereby can solve the problem of safe disposal of plastics, also avoids its wide spread littering and thus reduce the environmental effect caused by inorganic waste and pet bottles in the country.

8. Recommendation

It is expected that by utilizing pet bottles in construction recycled materials, high strength, earthquake resistance and thermal comfort can be achieved in very low cost housing, benefiting residents that cannot afford to buy and operate heating and cooling systems. The results of this research should be disseminated to residents in across the country, so that the people can implement the changes themselves without having to pay huge amount of money in order to have a home that provides more strength, thermal comfort and is more sustainable.

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