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Section A-Research paper

Reshaping used PET bottles for Sustainable Construction

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Abstract: The present work focuses on sustainable construction by reusing the waste PET bottles. Using of PET bottle in construction as a brick element were seen in the past, but this type of construction requires more mortar due to the cylindrical-frustum shape of PET bottles. The present work is to change the cylindrical-frustum shape of used PET bottles to a hollow rectangular prism using heating and semi-molding techniques without shredding the plastic bottle. Further, the shape of PET bottle will be in quasi-rectangular prism and filling it with a soil/sand material to use as a construction material alternative to bricks. The study shows that the PET bottle construction has good strength similar to clay burnt bricks. This type of PET bottle brick can be used as load-bearing walls for single-story buildings and infill walls for framed structures. Using PET bottles in buildings as a replacement for traditional bricks can solve the problem of environmental damage. The fusion is not involved in process of reshaping and reusing, and therefore saves energy and has less impact on the environment.

Keywords:PET bottle, quasi-rectangular prism,compressive strength

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1. Introduction

Sustainable construction refers to building with renewable and recyclable resources and materials. During construction projects, care must be taken to reduce waste and energy consumption where possible and protect the natural environment around the site. The result of a sustainable construction project must be an environmentally friendly building or surrounding environment.

The world now produces more than 380 million tons of plastic every year, which could end up as pollutants that enter our natural environment and oceans. Plastic is not biodegradable which adds to greenhouse gas emissions. If plasticsare burned, harmful gases like dioxins, furans, mercury, and polychlorinated biphenyls are produced which is a threat to living things on the Earth. Therefore, it is better to reuse or recycle plastic. There has been an invention of single-use plastics. Single-use plastics, or disposable plastics, areused only once before they are thrown away or recycled. These items include plastic bags, straws, coffee stirrers, soda bottles, water bottles, and most food packaging. At events and in meetings, it is easy to see the use of plastic bottles in huge numbers. These bottles are known as PET plastic bottles. PET stands for polyethylene terephthalate, which is a type of resin and a form of polyester. Plastic PET bottles are used widely across the world due to their low cost and easy application. PET bottles are one of the disposable materials for liquid-containing materials. In addition to its advantages such as good strength, thermo-stability, gas barrier, non-reactive, shatterproof, lightweight, and transparent properties. However, PET bottles generate more toxins during manufacture and release toxic chemicals into the ground during their degradable time, which is normally high in other words, PET does notbreak down, it contributes to plastic pollution. It breaks into tiny pieces and can enter the food chain. Due to their non-biodegradable properties, PET bottles are considered hazardous materials. The world is discovering how to reuse the plastic waste in a different way to reduce negative environmental effects.

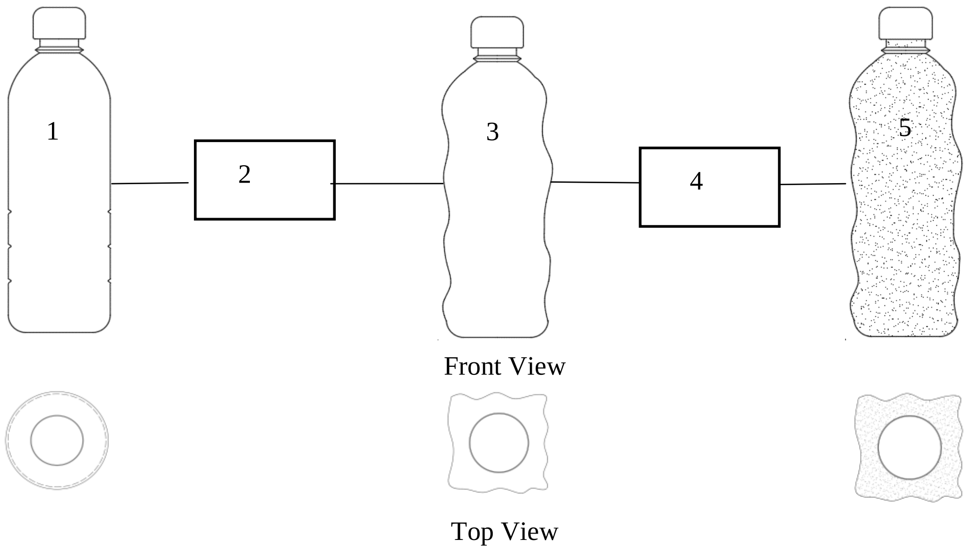
The Butakoola Village Association for Development (BUVAD) initiated the first plastic bottle building project in Africa in Uganda in 2010, in the Cayuga district. The idea followed a BUVAD community survey in 2009 that revealed many farmers in Kayunga were experiencing low crop yields due to poor soil fertility, which resulted from the presence of waste plastics, such as bottles and polythene bags, in the soil (Simanshu et. al. 2017). Haque (2019) discussed the use of PET bottles as a plastic brick used in the existing Rohingya refugee camp and the newly proposed displacement camp on the coastal island—Bhasan Char—as construction material to build new shelters. Azhdarpour et al. (2016) studied the effects of adding plastic waste particles to the engineering properties of concrete. Results show that the added plastic fragments changed both the physical and strength-related properties of newly produced concrete. Awoyera and Adesina (2020) concluded that the use of plastic wastes for construction applications would improve the sustainability of the environment significantly, and serve as a reliable source of materials for construction purposes. Aneke and Shabangu (2021) investigated the production of green bricks for masonry structures made using scrap plastic waste and foundry sand. In the recent decade, people from weak economic countries started using PET bottles in construction, by adding sand/soil/inorganic material inside the bottles and making them resistant to compressive strength. It can be seen that there is a use for PET bottles as a construction material. Due to the cylindrical shape of PET bottles, more quantity of cement mortar is required to construct a wall. In this study, the cylindrical prism-shape of the PET bottles is modified into a quasi-rectangular shape using semi-molding techniques and used as a construction material.

2. Experimental Study

2.1 Preparation of Sample:

The used PET bottles are collected and the stickers are removed. The flexible sponge of a rectangular shape is inserted inside the bottle through the opening at the top of the bottle. Hot air is blown on the outer surface of the PET bottles using a hot air blower fan. Due to the low thermal capacity of plastic, it tries to change its shape according to the mold prepared (flexible sponge in a rectangular shape). Further, allow the PET bottle to cool down, and a quasi-shaped rectangular PET bottle is made. Remove the flexible sponge and add a layer of soil/sand/inorganic waste material until the bottle is fully packed. PET bottles for construction are made in a quasi-rectangular prism shape. Figure 1 shows the typical making process of PET bottle Brick. Figure 2 shows the actual experimental PET bottle-making process using a flexible sponge and the application of Hot Air.

Fig. 1: A typical making process of PET bottle Brick



1 – Used PET Bottle
2 – Semi-Molding Arrangement
3 – PET Bottle in Modified Shape
4 – Arrangement for Sand/Soil/Inorganic material filling
5 – PET Bottle Brick

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Fig 2:Experimental Process of preparation of PET Bottles (a) Before the application of Hot Air (b) During the application of Hot Air (c) PET bottle in quasi rectangular shape after sand/soil filling

2.2 Test Sample Preparation

The reshaped PET brick prepared is planned to use as a masonry wall. To find the compressive strength of the masonry wall, PET bottles are placed in a horizontal direction as layer-by-layer. English bond is used for preparing the sample as shown in Figure 3. The nominal mix of Cement mortar 1:4 is used for preparing the masonry sample. The average size of the PET block sample is a length of 260mm, a width of 235mm, and a height of 250mm. It is to be noted that the size of the masonry block tested for compressive strength is not in standard size due to PET bottle shape and size.

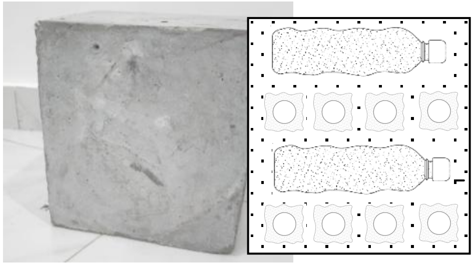

Fig 3: PET Brick masonry block a) Line sketch showing PET brick arrangements b) PET brick Masonry block

2.3 Compressive Strength test

The compressive strength test is carried out in two phases, one for PET brick alone and the other with hardened PET brick masonry block. Several tests have been carried out for PET brick in the vertical direction and horizontal direction as shown in Fig. 4. The figure shows the PET bottle brick test failure mode, when PET brick is placed in a vertical direction and a horizontal direction.

Fig 4: Failure mode a) PET brick in Vertical direction b) PET brick in a horizontal direction

The strength of hardened PET brick masonry block to withstand maximum compressive load was determined through a compressive strength test. Six samples were preparedwith a Cement Mortar ratio of 1:4. Samples are allowed to cure by air for 1 day and by water till the 28th day. The dimensions are measured for all the samples. The samples are placed in a compression testing machine and tested against compressive loads. Fig 5. Shows the test arrangements and mode of block failure.

Fig 5: a) Sample testing arrangements b) Failure mode

3. Results and Discussions

Test results for the PET bottle brick are shown in Table 4. It can be seen that there is a small difference in the size of the bricks, which is in an acceptable range and similarly in mass difference in each sample this is due to volume difference, filling material density, and due to manual filling. However, the bricks can achieve good compressive strength as listed in Table 1. When the individual PET brick is placed vertically, it can be seen that failure is initiated similarly to buckling and have a very less failure load resulting in less compressive strength. Where the sample is placed in the horizontal direction, the compressive failure load is increased resulting in higher compressive strength. In actual construction practice, the PET brick is placed horizontally along with mortar to form PET block masonry.

Table 1 – Compressive Stress for PET brick

Sample No.	Mass of sample Including bottle (gm)	Average Length (mm)	Average Diameter (mm)	Direction of Loading	Load Failure (kN)	Compressive strength (N/mm^2)
1.	512.30	199	48	Vertical	6.8	2.95
2.	580.99	196	49	Vertical	6.2	2.58
3.	545.28	195	45	Vertical	5.9	2.91
4.	527.73	192	47	Horizontal	156	17.28
5.	448.89	198	46	Horizontal	119	13.06
6.	508.74	198	45	Horizontal	142.4	15.98
7.	545.46	197	47	Horizontal	140.2	15.14

For PET block masonry, the failure of blocks is initiated between the joints of PET bottles (mortar). The entire failed model shows that there is no failure found in PET brick alone, this is due to the high compressive strength of PET bottles and the flexibility property of the plastic. The first cracks are initiated at mortar levels and failure of mortar is noticed at maximum compressive load as shown in Table 2 as failure load. The test results show that PET bottles can be used in construction. Further seismic performance of PET brick infill walls can be studied using the infill wall strut model (Durai, 2016 & Haran et.al 2016) to understand its behavior and contribution to lateral strength.Performance can be evaluated using seismic fragility curves similar like work carried out by Karthicket. al, (2017).

Table 2 –Compressive Stress for PET masonry block

Sample No.	Failure load kN	Average Area mm^2	Compressive Stress N/mm^2
1.	262	61100	4.28
2.	177	61100	2.89
3.	229	61100	3.75
4.	260	61100	4.25
5.	213	61100	3.48
6.	243	61100	3.98

4. Conclusion

In this study, PET bottles are changed to a quasi-rectangular shape using semi-molding techniques and then filled with sand to form a PET bottle brick. The novelty of the work lies in the development of a quasi-rectangular shape PET bottle. Due to the change of shape from cylindrical to rectangular shape, the quantity of mortar used in the joints is reduced. Bonding strength between PET bottle and mortar is increased. As it is observed that failure of the block starts at the mortar joint level due to the strength of the mortar being less than the PET brick strength. It is seen that PET bottles can be used for construction purpose as it shows good compressive strength equivalent to brick masonry blocks. PET bottles can be used as non-load-bearing walls, such as infill walls, partition walls, boundary walls, temporary structures, etc. The advantages of using PET bottles used in construction are low cost, durable, can be constructed aesthetically, reducing environmental pollution, etc. And fusion is not involved during the process of reshaping and reusing, and therefore saves energy and has less impact on the environment for sustainable construction.

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