

Recycled Plastic Bottles: A Sustainable Solution for Building Materials

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ABSTRACT:

Recycled plastic bottles are emerging as a highly efficient and sustainable building material, offering numerous environmental and practical benefits. By repurposing plastic waste, these bottles reduce the strain on landfills and lower the demand for virgin materials, contributing to significant waste reduction. The inherent properties of recycled plastic, such as durability, resistance to moisture, and insulating capabilities, make it a viable alternative for various construction applications, from insulation and roofing to structural components. Additionally, the use of recycled plastic bottles can lead to cost savings and promote greener construction practices, making it a compelling option in the quest for eco-friendly building solutions. In this work, plastic brick was created using a 500 mL bottle that was manually compacted and filled with waste polythene that had air dried. The brick was shaped like a typical clay brick using a cardboard frame. The filled bottle was positioned in the middle of the frame, and the entire frame was covered with mortar that had been manually blended to the specified dimensions. When the prepared brick samples were put through a compression test, the average strength for the 14- and 28-day crushing age samples was 2.88 and 3.29 N/mm, respectively. This showed that the bricks had a great potential for usage in construction projects. In addition to controlling plastic waste and mitigating the risk posed by natural disasters in the camps for displaced people, using plastic bricks can be an affordable, practical, and sustainable means of creating a sturdy and secure living environment.

Keywords: Building material; plastic waste; sustainable; mortar; construction applications.

1. INTRODUCTION

Over the past half-century, plastics have been instrumental in advancing people's quality of life everywhere [1]. Plastic has made numerous new advancements feasible for industries such as construction, packaging, industrial uses, healthcare and medical facilities, and others [2]. Yet because plastic waste takes too long to biodegrade in the environment, it has now become a global problem due to improper disposal, which has negative effects on the environment including air, land, and marine pollution, ecosystem damage, negative effects on aquatic species, and more [3]. Plastic garbage has negative physical and chemical consequences on people's health. In many parts of the world, Eco brick, also known as Plastic brick, was developed to build homes for those living in poverty. In low-income societies in particular, waste polyethylene terephthalate (PET) plastic bottles are recycled and reused as building materials. This helps prevent the

negative effects of plastic waste. Nowadays, plastic bottles are commonplace and account for a large amount of garbage and greenhouse gas emissions worldwide (BTI, 2019). Because PET bottles are simple to reuse in construction projects and provide the following advantages, reuse is preferable to recycling (BTI, 2019).

- Minimizes waste,
- Uses locally sourced materials,
- Protects the environment.
- Reduces carbon emissions.
- Cheap.
- Simple to use and low tech.

In order to construct sturdy and secure shelters for the coastal area people in their displaced settlements, the current study aims to evaluate the suitability and efficiency of integrating plastic brick as the building material. Each brick sample is prepared using a 500 mL waste PET plastic bottle

and then put through a compressive strength test.
How the plastic bottles are thrown in garbage area

shown in Fig. 1.



Figure.1 Plastic Bottles

1. PLASTIC POLLUTION SCENARIO

Plastic was invented in 1907 and has since become a very popular and commonly used material worldwide. Due to their non-biodegradable nature, the hydrocarbon molecules utilized in their synthesis (which come from natural gas and oil refinement), and the difficulties associated with properly disposing of their waste, plastics are the main environmental concern. Seventy-five percent of the plastic generated worldwide is waste, and since 2000, the world has produced as much plastic as all the years combined. A third of this plastic garbage is estimated to have entered the environment as freshwater, marine, or land pollution as a result of improper handling [4]. As of 2015, it was predicted that 6300 million metric tons of plastic waste were produced annually, of which 79% ended up in landfills and other environmental areas before entering the ocean. Marine creatures and other critters consume plastic that is constantly

disintegrating and getting smaller in the water. It is predicted that by 2050, there will be more plastic than fish in the world's oceans. The soil, lakes, and oceans on Earth are contaminated by macro, micro, and nanoplastics, which harm natural ecosystems, kill species, and accelerate climate change. Because of insufficient infrastructure for trash disposal, mismanaged garbage is a major contributor to plastic pollution and is most prevalent in low- and middle-income nations. Plastic trash ends up in poorly managed landfills or opens dumping zones because these nations have little recycling capability and fewer efficient end-of-life waste management systems. More than 76% of the plastic garbage generated in low-income nations in 2016 was improperly disposed of [5]. The scarcity of recyclable plastic materials for use, the high cost of operation and recycling, and the absence of available technologies have resulted in an ineffective method for managing plastic trash [6].

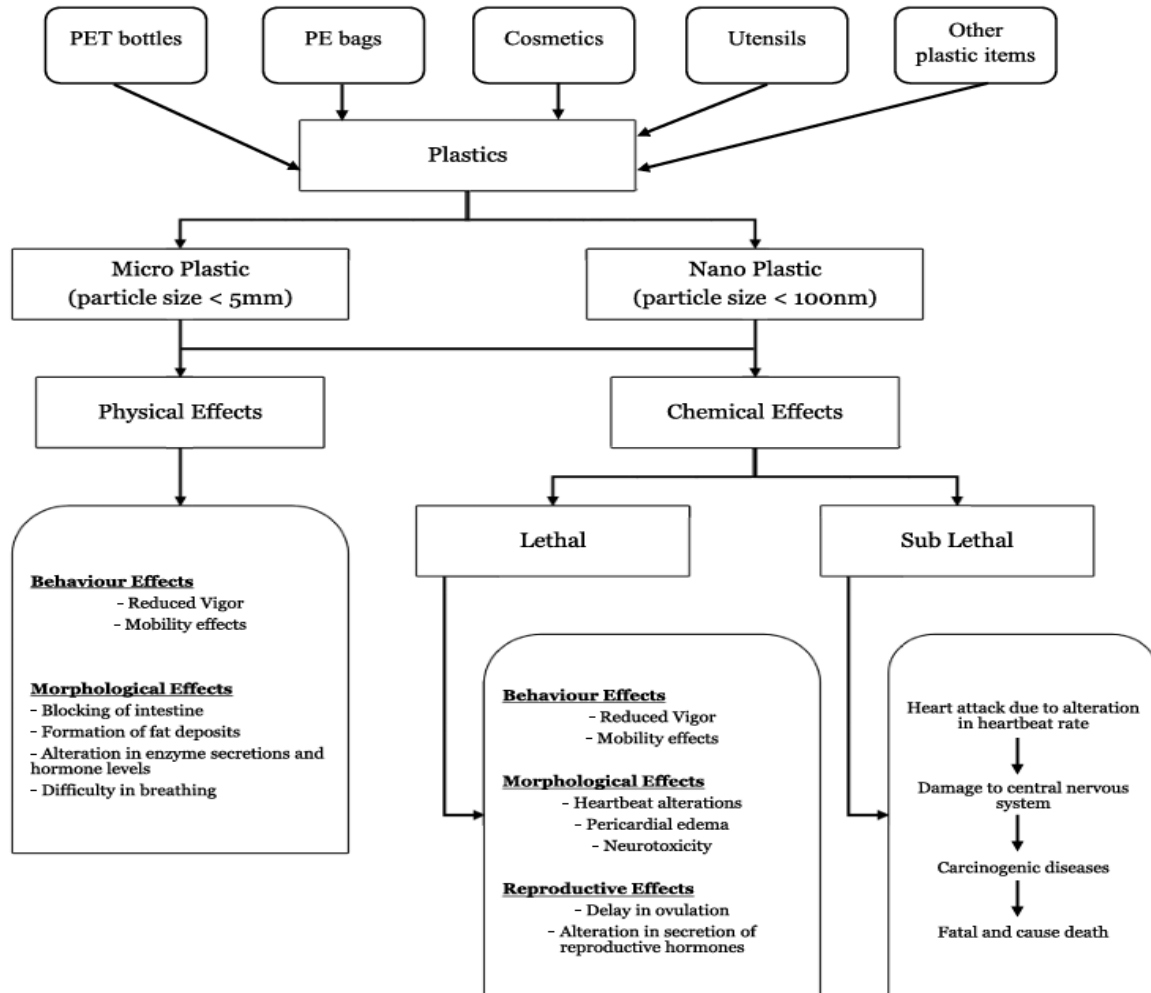


Fig 2. Environmental impact of plastic waste

2. ECO- BRICK AND ITS EFFICIENCY

Recycling is the process of converting waste products into resources for the economy, environment, and society [8]. It's the process of using recyclable waste materials to see how much potential they have for reuse or conversion into valuable products. In light of a more environmentally conscious future, study is being done on the low cost and lightweight nature of PET waste plastic bottles as potential building materials for brick production. This process was created to address the issues of disposing of plastic garbage in both urban and rural locations, controlling it, and the resulting environmental damage [9].

According to, German architect Andrias Froese first proposed the idea of using waste PET plastic bottles

in building construction in South America in 2000–2001. PET plastic bottles were installed within the walls along with mortars to shape a structure (i.e., houses, water tanks). These plastic bottles included filler made of mud, sand, soil, or landfill material. Nigeria, South Africa, Norway, the Philippines, and India were among the nations that swiftly embraced the technology [10]. To satisfy the current and future demands of its population, the Nigerian government devised a plan in 2004 to build 8.0 million new dwellings, 5.0 million of which would be in urban areas and 3.0 million in rural areas. Through the use of computer simulated modeling, prepared WPC bricks were designed and validated. Ala Loul et al. carried out a similar work in which they manufactured interlocking plastic bricks by

combining shredded waste PET plastic bottles with PU binder. With an average compressive strength value of 4.30 MPa, the created brick with a mixed PET/PU composition of 0.60/0.40 was found to be appropriate for building partition walls. According to [10], walls built of plastic brick are 20 times more load resistant than walls made of conventional bricks and more earthquake resistant because of the compaction of the filler material in the bottles.

In order to create plastic bottle-made cylinders for this investigation, 1.0L waste PET plastic bottles were filled with sand. Comparing the obtained compressive strength (19.9 MPa) to regularly used concrete cylinders; it was evident that employing cylinders built from plastic bottles was more compatible. In particular, used eight hollow 500 mL PET plastic bottles in concrete blocks that had the following dimensions: L x B x H = 400 mm x 200 mm x 200 mm. For the 28-day sample, the maximum compressive strength of 10.20 MPa was achieved, however for the 7-day sample, the strength was lower at 6.03 MPa. Homes constructed with plastic brick are bulletproof and strong enough to shield occupants from the damaging effects of cyclones and other natural catastrophes [11]. According to Antico et al. (2017), the majority of construction projects utilizing plastic bricks are community-based initiatives in which local communities collaborate to build housing, educational facilities, and recreational areas. In addition, Antico et al. (2017) found that communities, governments, and non-governmental organizations (NGOs) saw plastic brick as a low-cost building material for social projects and as a potential recycling solution to lower plastic waste disposal volumes [12].

3. Materials and method

3.1. Materials

The following materials were used in this study:

Cement: In order to conceal the plastic bottle and mold the plastic brick into the shape of a typical clay brick for appropriate usage, Portland cement (Type-1) was utilized to prepare the mortar mixture.

Fine Sand: Fine sand was utilized to make the mortar mixture and to fill the plastic bottle. The sand was

allowed to air dry at a laboratory temperature of 25 °C (± 2 °C). The sieve analysis resulted in a fineness modulus (FM) of 1.98, indicating an average particle size of between 0.15 and 0.30 mm.

Plastic Bottle: With a density of 1.38–1.39 g/cm, PET bottles are the most often used material.

To determine which 500 mL PET plastic bottles had the best compressive strength, a total of eight bottles in various sizes and shapes were used. To maintain the study's purpose, these bottles with their sealing corks were selected at random from household and roadside waste dumps.

Box cardboard: In addition to the increase in other wastes, food and paper wastes have made significant contributions to Bangladesh's solid waste stream. Paper and food waste were around 7.22% and 75.64%, respectively, in 2014 [13]. Because cardboard is a necessary component of these two waste streams, the study decided to use it as the framing material.

3.2 Waste PET bottle utilization and frame development

Sand was used as the filler material in a 500 mL PET waste plastic bottle to create the plastic brick used in this study. Prior to moving on to the next stage, the 500 mL bottles were thoroughly cleaned in freshwater and allowed to dry. Then, using a funnel, fine sand was completely poured into the sample bottles and compacted into three layers, each of which received 25 blows from a tamping bar. To minimize any kind of cavities in the compaction and enhance the less compacted layers, a general quality check was carried out. Later, cardboards that had been used to prepare each brick sample were used to assemble the frames. (L x B x H) = (9.5 in x 3.5 in x 3 in) = (241mm x 88.9mm x 76.2mm) was selected as the casing measurement. In order to bond the cardboard in the shape of a traditional clay brick, packaging tape was wrapped around the entire casing after it had been hardened and cut to the specified mark dimensions. This process was followed by preparing each casing for the test samples. The cardboard frame and sand-filled PET bottle that were utilized in this work to create plastic brick samples are shown in Figs. 3 and 4, respectively.



Fig.3 Plastic Bottle



Fig.4 Box Cardboard



Fig.4 Brick Preparation

3.3. Preparation of eco-brick sample

A 1:6 cement-to-sand ratio and mortar proportion were used to create the cement-sand blend with water. After 15 minutes of hand mixing, the mortar was blended. Once the blend was finished, a 0.5-inch layer was cast into the cardboard frame's base. At that time, the sand-compacted plastic bottle was placed in the middle of the casing so that the remaining frame faces could retain 0.5 inches of clear cover. Subsequently, mortar was filled into the frame to the designated measurements. Following the mortar pouring process, the plastic brick was allowed to come loose from the cardboard frame for twenty-four hours at a temperature of 25 C (± 2 C). After a day, the brick samples were removed from the cardboard frame and immersed in fresh water to facilitate curing. For the plastic brick samples, a total curing period was 12 and 21 respectively (see Fig. 5).

3.4 Testing of compressive strength

According to Mokhtar et al. (2016), compressive strength is the highest compressive stress a material can sustain without breaking [14]. Three samples with a 12-day curing duration and two samples with a 22-day curing period were made, and they were tested for compression using a 1000 KN capacity and 0.1 KN precision in a UTM (universal testing machine). In order to simulate the manner that bricks are used in wall structures, each sample brick

was placed horizontally on the testing plate (see Fig.6) of the UTM. This allowed it to be exposed to diametric compression mode. Later, eq. (1) was used to determine the samples' compressive strength [15].

$$C = P/A$$

Where

C = compressive strength

P = max. Load at failure

4. RESULTS AND DISCUSSION

Sample number 3's maximum compressive strength at 12 days of crushing age is 3.60 N/mm², while sample no. 4's maximum compressive strength at 22 days of crushing age is 4.45 N/mm². The Public Works Department (PWD) states that for clay bricks, the minimum allowable average compressive strength is 5.20 N/mm², for hollow blocks it is 2.80 N/mm², and for concrete blocks it is 2.50 N/mm² per ten randomly selected samples taken from the contractor's stockpile of 1000 or a portion of it. The average strength values of the brick samples with a 12-day crushing age (2.88 N/mm²) and a 22-day crushing age (3.29 N/mm²), when compared to the compressive strength standard established by PWD (2005), exceeded the standard value for concrete and hollow blocks but did not satisfy the norm for clay brick.



Fig. 6 Eco Bricks



Fig.7 Compression testing of brick

The reason for the samples' lower compressive strength values is that there was a significant discrepancy between the mortar binder's modulus of elasticity and the outer surface of the utilized plastic bottles, which led to the development of tensile stresses in the brick samples. However, a stronger friction between the used bottles and mortar binder can be maintained by placing a small scratch or mild perforation to the bottles' outer surface [16]. This

can solve the problem and is anticipated to improve the compressive strength of the plastic brick. A comparison of plastic and regular clay brick wall structures is presented in Table 1, which indicates that plastic brick is more suitable than regular clay brick for construction projects in terms of cost, speed of construction, structural strength, and material usage.



Fig. 8 Wall of eco bricks

The used PET bottles must first be thoroughly cleaned and dried before being used to build a structure out of plastic brick. After that, only non-biodegradable things like dirt, sand, broken-up

plastic garbage, etc., should be placed inside the bottles. With a tamping bar or stick, these inorganic components must be firmly packed into the bottles so that there are no gaps, and the bottles must then

be sealed. Through this technique, the shelters will have a sturdy wall structure that can withstand the risks caused by mudslides, severe winds, rain, and storms. Additionally, if the old bottle is damaged, it can be changed out for a new one. According to Muyen et al. (2016), the cost of preparing a plastic brick is just Rs. 4, while a conventional brick costs approximately Rs. 8 (BBS, 2019). This makes plastic bricks an affordable option with appropriate building materials for the population of refugees.

5. CONCLUSION

The study's plastic brick samples and their corresponding compressive strengths (maximum 4.46 N/mm and 3.60 N/mm² for 28-day and 14-day samples, respectively) indicate that by employing this recycling process, rather than using bamboo and plastic sheet, to build shelters in displacement camps is a sustainable way to provide safe havens for refugees while also reducing the amount of plastic waste and degradation that the country produces. In order to give the coastal area people a suitable and safe place to live, a hand combination of cement and sand combined with used plastic bottles turned out to be an inexpensive, environmentally friendly construction option against concerns related to lack of financial support and environmental threats.

Plastic recycling industry to work together to integrate a "green business model" by using locally produced plastic garbage to prepare recyclable, eco-friendly, and resource-efficient plastic bricks. Nonetheless, the current study can expand the future scope of understanding the dispersion and crushing pattern of compressive strength test over these bricks by testing additional samples and refining the results. Additionally, it is advised to look into the following: the modulus of elasticity and the modulus of rupture; combined compression and bending with varying filler content (such as dirt, mud, and paper waste); flexural bending and bond strength of mortar binder (with and without perforation in bottles); and the overall structural behavior of plastic brick to reliably utilize as masonry [16]. Future studies should also examine the environmental effects of using plastic waste as a raw

material for bricks. This can be done by comparing the carbon, energy, and plastic footprints of the waste utilization and brick manufacturing processes before and after they occur, as well as by calculating the air quality index for the areas that are home to landfills and brick kilns. The results of the study regarding the average compressive strength of the plastic brick samples have created a foundation and demonstrated the viability of using these bricks as construction materials in order to get rid of plastic waste and give the poor access to affordable housing.

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