

Research on Properties of Ecobricks and its Possible Applications

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Abstract. Ecobricks are bricks made from garbage or plastic that hasn't been recycled. Traditional brick wall tiles are constructed of bricks and mortar, which are not very eco-friendly and have a significant potential for global warming. Therefore, this paper suggests the utilization of ecobricks instead. Plastic bottle bricks, the most popular kind of ecobricks, are created by putting inorganic fillers like sand into plastic polyethylene terephthalate (PET) bottles. Besides the environmental issue, ecobricks also have the advantage of being affordable. The walls and foundations formed of plastic bottle bricks are able to stand rigidly on their own thanks to the self-standing qualities of plastic bottles, thus it is less expensive. As a result, plastic waste can be collected and used in some underdeveloped countries where insufficient waste management and inadequate funding are major concerns for the development of environmentally friendly initiatives. Refugee camps or low-income neighborhoods are examples of potential locations. This paper makes a suggestion on the potential application of plastic bottle bricks for use in new construction shelters of a new displacement camp that has been suggested for the Bangladeshi island of Bhasan Char.

Keywords: Plastic bottle brick; ecobrick; material; wastes; refugee camp.

1. Introduction

Walls have multiple functions in terms of load-bearing, spatial separation and maintaining structural stiffness. Traditional walls are usually made of cement, aggregate, and water. However, the burning process used to make cement and bricks releases greenhouse gases such as carbon dioxide, which can contribute to global warming. Data from the “Global State of Buildings and Construction Report 2019” shows that in 2018, the buildings and construction sector accounted for 36% of total energy consumption and 39% of process-related CO₂ emissions out of all sectors, with 11% of the CO₂ emissions came from the production of building products and materials including steel, cement, and glass [1].

There are several ways of reducing the impacts brought from the construction industry and wastes, one of them being to reuse some materials to reduce waste generation since the disposed and untreated wastes will generate a significant amount of methane, a form of greenhouse gas, into the atmosphere [2]. Recent article has revealed that over 90% of the plastic garbage produced in the US is not recycled, with polyethylene terephthalate (PET) being the most utilised material [3]. Population increase, low production costs, and the numerous uses of plastics all contribute to the massive generation of plastic garbage [4]. There is also a general lack of understanding and knowledge about waste management in the public so the links between every stage of the entire recycling system are generally weak. As a result, using plastic bottle as plastic bottle bricks is a good way of recycling waste plastic bottles around the world [4].

Recently, a variety of initiatives led by individuals, communities, or nongovernmental organisations (NGOs) have contributed to the collection and recycling of plastic bottles for use as construction materials around the world. The first home made of plastic bottle bricks was constructed in Nigeria and is known as The Bottle House [5]. Plastic bottle bricks are now being successfully employed in a number of nations across the world. Before people discover any more practical ways of decomposing and reducing the amount of plastic trash present in our lives, plastic bottle bricks may be a good interim solution to the global warming problem and plastic pollution.

2. Building Houses with Plastic Bottle Bricks

In addition to the previously noted Bottle House in Nigeria, where almost 8,500 recycled plastic bottles were used to construct a house with two bedrooms, plastic bottle bricks are also used in many other countries to construct eco-friendly buildings. For instance, study showed that Honduras used almost 8,000 recycled plastic bottles to construct green homes. In addition, barriers around the Iquazu Falls in Argentina were built using 1,000,200 PET plastic bottles, etc. [6].

2.1. Properties of Plastic Bottle Bricks

The fact that plastics are durable, anticorrosive, light weight, good sound insulated, high thermal insulated, and have a long life span, makes plastics a good alternative material for construction. Besides these properties, plastic bottle bricks are also self-supporting structures. As shown in Fig. 1, if plastic bottles are used to build structures, they can stand on their own to produce a wall [7]. In practice, the plastic bottles are attached to each other using a kind of mesh. The gaps between the bricks are usually filled with cob mixture. The walls made of plastic bottles are also consolidated by mixture of cement and lime, which in contrast to traditional bricks made completely of cement and lime, using plastic bottle bricks can cost much less. Accordingly, ecobricks including plastic bottle bricks are a good alternative if the country finds it quite difficult to implement expensive sustainable solutions. Simple trash pickup or removal can be very effective in reducing the country's solid waste disposal burden if the wastes are being utilized as building materials. Furthermore, since most plastic waste is likely to accumulate near the ocean or in open landfills, these types of bricks can significantly improve the environment in those areas.



Fig. 1 Plastic bottles stand on each other [7]

The walls made of these plastic bottle bricks are very good at insulation which means they can provide thermal comfort. With better insulation, there can be less cost incurred due to heating and cooling during the operation period of the house. Since plastic bottle bricks have high sound reduction index, houses made of these bricks can have good sound insulation effects. What's more, plastic bottle bricks do not permit light transmission so through proper design, there can be complete blockage of the light from passing through the walls. Both of these two properties can lead to better living standards [7].

Usually, the house with plastic bottle brick walls has a roof that is made of wood or corrugated metal. However, these bricks can also be used for the building's roof. Due to its high thermal isolation property, the house can be better insulated compared to that made of conventional roofs. The methodology of constructing a house with plastic bottle bricks can be illustrated in Fig. 2 [8].

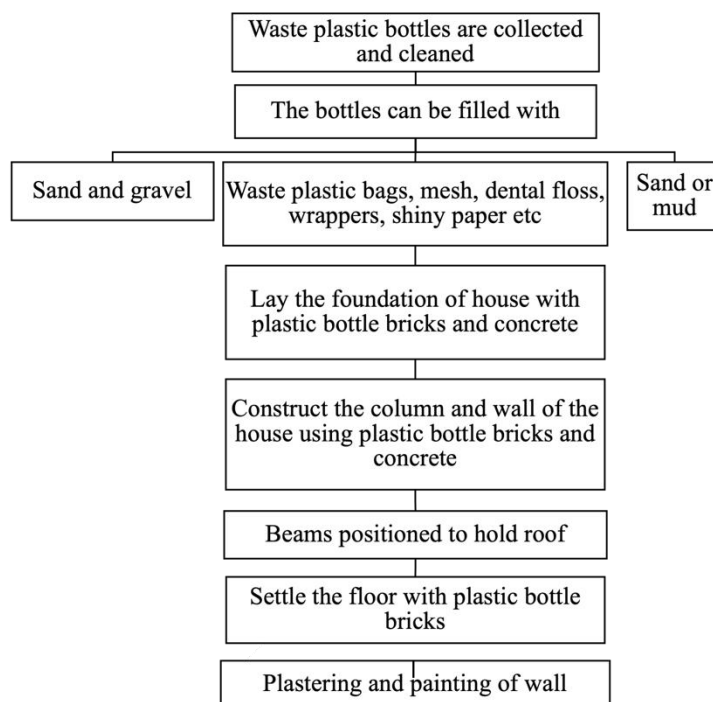


Fig. 2 Methodology of constructing a house with plastic bottle bricks [8]

2.2. Bottle House in Yelwa, Nigeria

The Development Association for Renewable Energies (DARE), a Nigeria-based nongovernmental organisation, proposed the concept of constructing the first Bottle House in the community of Yelwa in Nigeria. Plastic bottle bricks were used to build the bungalow-style home, which has two rooms. Fig. 3-Fig. 5 show the how the local people were constructing the house with plastic bottle bricks. The built house is floodproof, bulletproof, fireproof, quakeproof, and has a constant 64 degrees Fahrenheit (17 Celsius degrees) internal temperature all year round [6]. This house made of recycled plastic bottles is also cost-effectiveness, durable, energy efficient and environmentally compatible [6].

During the construction process, the plastic bottles are cleaned, selected, and then filled with inorganic fillings such as sand. As shown in Fig.3, the plastic bottle bricks are laid one upon each other due to their self-standing properties. After that, they are set (Fig. 4) and linked together using a network of strings. The roofs and walls of the dwellings are then built by the workers using mortar and mud. In Fig. 5, the local resident is plastering the plastic bottle wall with mortar and mud. The mortar inside the house is proved to be able to compact with the hot Nigerian climate since plastic bottle bricks have good thermal isolation and they can block the house from intense [9]. However, since sand-filled bottles have low weight themselves, the houses that are built with these plastic bottle bricks can only be less than or equal to three stories high [10]. After the completing a bottle brick wall, wall finishing is proceeded. It is a two-step process consisting of plastering and painting. Plastering is to use plaster, which is made up of lime or gypsum, sand or cement and water-soluble polymers. to cover up the imperfections of the wall and act as a wall coating. At the same time, painting makes the wall more colorful.

After successfully constructing The Bottle House, DARE also received support from the African Community Trust, an NGO based in London. They are working together and they hope to build similar buildings in the future since these kinds of projects can not only improve the housing shortage that is currently suffering a lot of Nigerian people but also clean up the plastic waste in the country and reduce plastic pollution [10].



Fig. 3 Workers laying plastic bottle bricks for The Bottle House [10]



Fig. 4 Settings of plastic bottle bricks for the Bottle House [10]



Fig. 5 Workers plastering the wall of the Bottle House [10]

3. Works with Bricks and Plastic Bottle Bricks

To use the plastic bottles in construction, plastic bottle bricks are made by filling plastic bottles with inorganic wastes such as sand, soil, foams or other plastics [11]. Utilizing these inorganic filler materials in PET plastic bottles rather than the traditional bricks can make it a viable recycling strategy to minimize significant amounts of plastic trash since polymers take a long time to breakdown. [5]. According to reviewed articles, buildings made of plastic bottle bricks require less amount of cement. Only about 75% of the bricks need to be covered with concrete and the construction price is 40% lower than for “traditional” buildings [12]. In light of their reduced reliance on bricks and cement, which results in a reduction in CO₂ emissions, plastic bottle bricks are therefore more energy-efficient than conventional bricks.

Cost of using a plastic bottle brick and that of using a traditional brick can be compared by using the simple estimation below. Assumptions taken for this calculation are [13]:

(1) The production of plastic bottle brick is assumed to be taking place in Bangladesh and the currency unites are in Bangladeshi Taka.

(2) An average value of 8 Taka is used for one kilogram of PET bottle.

(3) The cost of sand fill is taken as 150 Taka for 1 of sand.

(4) An average weight of sand in one bottle is taken as 862 grams (890 for the bottle with sand and 28 grams for the empty bottle).

(5) Bulk density of sand is taken as 1.28 ton/m^3 .

(6) The cost for one worker filling one plastic bottle with soil is 2 Taka.

Therefore, the weight of 1 sand will be 1280kg. In a usual 500ml PET bottle with the average weight at about 28 grams, the number of bottles in one kilogram will approximately be $36(1000 \div 28)$. The cost of one 500ml PET bottle will be around 0.22 Taka and the cost of 1kg sand will be about 0.12 Taka ($150 \div 1280$). The cost of sand in the bottle can be estimated by 0.10 Taka (0.862×0.11718).

Since the total cost incurred by producing one plastic bottle brick can be roughly divided into the pricing of an empty plastic bottle, the value of sands and gravels, and the price of labor, a rough estimation of the total cost for one plastic bottle brick will be 2.32 Taka.

$$\text{Total cost for one plastic bottle brick} = \text{Tk. } (0.22 + 0.10 + 2.00) = \text{Tk. } 2.32 \quad (1)$$

As shown in the calculation, in Bangladesh, it will cost 2.32BDT to produce one plastic bottle brick. However, if a conventional brick is used, it will usually cost about 10.80 BDT [12]. Therefore, there will be a profit of Tk8.48 per plastic bottle brick generated ($\text{profit} = 10.8 - 2.32 = 8.48$) This will be a cost-effective and easy solution for the low income population.

4. Paradoxes of Plastics Bottle Bricks

Firstly, the public usually have doubts about the strength of bottle bricks since they are made from plastic bottles. Even plastics may appear strong, they are durable and can deform under pressure. Therefore, when the bricks are subject to high pressure, they may deform which limits its utility in any weight bearing application. This would limit its utility in any typical weight bearing application. However, more recent studies have shown that bottle bricks are even stronger than the traditional bricks. The compacted sand inside the bottles made the bottle brick almost 20 times stronger than normal bricks [13]. As experienced by some researchers, who had tested the compressive strengths of five different PET bottle brick sizes 250ml, 500ml, 1250ml, 1500ml, 2000ml. The compressive strength of the 2000 ml brick measured is 17.44 MPa. Traditional bricks' typical compressive strength, in contrast, ranges from 1000Pa to 1500Pa [4].

Secondly, plastics are highly flammable, so they are thought to be very dangerous materials in the construction industry. Highly poisonous gases including dioxins, furans, mercury, and polychlorinated biphenyls will be discharged into the atmosphere in the event of a fire. However, the risk of a plastic bottle brick carrying fire is often overestimated due to misconceptions from the public of where the bricks are used in constructions. Most often, a plastic bottle brick is densely packed to a proper density as to minimize the risk of it catching fire. According to the Global Ecobrick Alliance (GEA), the best-practice guideline is to pack these plastic bottle bricks to the minimum density of 0.33g/ml. The Global Ecobrick Alliance (GEA) states that packing these plastic bottle bricks to a minimum density of 0.33g/ml is the recommended practise [14]. In which case, the volume of oxygen in the bottle will be kept to a minimum, lowering the risk of a fire. It is also important to lay the plastic bottle bricks horizontally in cob while constructing the walls. For foundation, they are half laid in cement and half in cob. The cob mortar is normally spaced out between the bottles by 3 to 5 cm. If these rules have been strictly followed during the construction, cob walls are virtually impossible to set on fire because they can remain intact long after wooden beams and floors have burned to ash. However, to further improve fire safety, earthen render or cement render are covered onto the exposed caps and bottoms to insulate the brick from air. Another way of improving fire resistance is by adding hydrated aluminum oxide or magnesium oxide to polyethylene or adding them

together with bromine or phosphorus compounds. These additions will decompose under fire and release water to absorb energy [14].

Thirdly, polyethene plastic bottles have well chemical resistance except to alkalis which will be able to hydrolyze them. Therefore, most plastics cannot endure alkaline. Portland cement, the common filler between plastic bottle bricks, has a pH of 12.5, which is extremely high. This highly alkaline property of cement will react with the plastic bottles, causing damage to structural integrity of the building. Solutions have been found that the best way to avoid failure is by adjusting the cement to a lower PH. GEA has recommended the construction to take place using earthen mortar [14]. It is an organic mixture cement composing of clay, sand, and straw. By using earthen mortar in between, the plastic bottle bricks, and the structure can remain intact when the bottles need to be extracted. This can happen several centuries later when our descendant needs to demolish the building. However, with Portland cement in between, the plastic bottle bricks will rupture under the action of cement before they can be extracted.

Lastly, properties of plastic bottle bricks are also easily affected by extreme weathers. When the weather is extremely hot, the bricks can become soft while when it is very cold, the plastics will become brittle. This may cause the microplastics and inorganic fillings to leech into the surrounding environment, causing immediate harm to the underground soil, eventually threatening the life of aquatic plants and animals. The majority of the time, however, mortar, cement, and paint are utilised to thoroughly cover plastic bottle bricks when they are employed in construction. As a result, there is no chance for the bricks to be exposed to UV, heat or frictional degradation which has the probability of causing leaching.

5. Application of plastic bottle bricks in refugee camps

The Rohingya people are groups of Indo-Aryan Islam groups which used to reside in Rakhine State, Myanmar. They now become stateless since 2017 so they fled from Myanmar to Bangladesh. According to the UN General Assembly (UNGA), approximately 1.1 million Rohingya had fled to Bangladesh. The refugees settled in the area of Bangladesh which does not have enough livelihood opportunities: monsoon rains, cyclones occur frequently [15].

Due to the limited living conditions and limited lands available as shown in Fig. 6, another solution is implemented which is moving the refugees to another island-Bhasan Char [16]. The island, with a total area of 40 square kilometers, was formed by Himalayan silt in 2006 where the government of Bangladesh moved 100,000 Rohingya refugees from the original refugee campus of Cox's Bazar by building a total of 1440 buildings including 120 cyclone shelters. The newly built refugee buildings finished in 2020 are shown in Fig. 7 which are made of traditional bricks and concrete [17].



Fig. 6 Kutupalong refugee camp in Bangladesh Cox's Bazar [16]



Fig. 7 A view of the newly built refugee camps in Bhasan Char [17]

However, a more sustainable solution may be employed in the future if more refugees need to be resettled. Since the management of plastic waste is less efficient than that in other industrialized nations, there are currently a lot of plastic waste around the area. By utilizing plastic bottle bricks instead of normal ones, there will be less cost and less CO₂ emission associated during the construction or operation process. Residents from the local community can construct their own shelters easily since plastic bottles are easily and locally available materials. From the calculation in part 3, buildings with plastic bottle bricks will also generate much less cost compared to that of conventional bricks during the construction period. The proposed idea can be supported with the evidence that a lot of projects which involve the use of plastic bottle bricks all over the world are projects where a lot of communities work with each other to reach a collective goal. In Nevada, the residents had built their first plastic bottle brick house which is anticyclone and durable using plastic bottle bricks. This project could possibly serve as a beneficial example for other parts of the world. [3].

By incorporating the refugees in a collective way, they can build their houses in environment friendly ways, so it brings better environmental protection and peaceful atmosphere in the community. More importantly, by incorporating plastic bottle bricks in the construction of refugee camps, the vulnerability of the shelters due to monsoon rains, heavy wind, cyclones can be mitigated, and less funding is needed.

Apart from building refugee camps using bricks, other secondary elements of the refugee community can also be built using this kind of material, including street furniture, pavements, children's playgrounds, community green spaces etc. Hence, further research on the use and properties of plastic bottle bricks or construction techniques that is required to be involved need to be carried on building communities in a more sustainable, safe, and cost-effective way.

6. Conclusion

(1) Plastic bottle bricks are bricks made from plastic bottles. The brick offers all the advantages of plastic bottles including durability, corrosion protection, sound and heat insulation, light weight, long service life, and self-supporting features. By placing the plastic bottles in a certain way, they can stand on their own and form a wall without the heavy use of mortar or mud to bond the material. What's more, production of plastic bottle bricks is cheap since much less cement or mortar is needed to bind the materials than the conventional bricks. Therefore, they are suitable for low income residents.

(2) Plastic bottle bricks have the potential to be used to build houses because of their high strength and comparatively inexpensive cost of production. These houses being made would be ecofriendly since this technique can help reduce the plastic wastes existing around the world.

(3) There are already some successful cases, for example in Nevada, where the people from the local community construct their own plastic bottle brick house using their own hand-made plastic

bottle bricks which could be a valuable example for other places of the world. Thus, some developing countries may learn from these examples and use plastic bottle bricks to effectively reduce and reuse plastic waste in areas where the management of plastic waste is less efficient and where there are insufficient funds. For example, the idea might be used in refugee camps where people cannot afford very expensive houses which can not only help improve community policing but also produce environment friendly effects. However, more research into the use of plastic bottle bricks and construction techniques using these new bricks is needed when new projects are undertaken in the future.

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