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Sustainable Bricks from Thermoplastic Waste and Cost Comparison with Traditional Bricks

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Abstract

With rapid globalization, consumerism, industrialization and greenhouse gas emission, the world's temperature is skyrocketing day by day which leads to climate change. Chemical, construction and textile industries are the biggest sources of environmental pollution, and thus sustainability issues are rising. The present world is going through several problems like overpopulation, poverty, greenhouse gas emission, and environmental pollution. Wastages like household wastages, municipal wastages, different synthetic polymers, thermoplastic wastes etc. have become a global problem. Every year, 300 million tons of plastic are being produced worldwide. Land fields, oceans, and the air are being polluted by plastic during and after the manufacturing processes. So, cultivation, human health, wild and marine lives are under threat. At present, harmful plastic can be converted into our resources by proper utilization. Proper utilization of these wastes will be beneficial in terms of both environment and the economy. This study focuses on manufacturing bricks from these wastes (Polyethylene, Polyethylene Terephthalate) as a way for the conversion of waste into resources. In the case of performance, the strength of the developed brick is very good and durable in comparison with the traditional one, as well as economical.

Keywords: Sustainability • Thermoplastic • Wastage • Polyethylene • Polyethylene terephthalate • Brick • Strength

Introduction

From Figures 1 and 2, The present world is largely dependent on plastic materials such as water bottles, drink cans, food packages, chemical packages, carry bags, Milk pouches, sacks, bin linings, cosmetics and detergent bottles, electrical fittings, knobs which are being used from household chores to industrial purposes because plastics are light weight, strong and durable [1]. As a result, the use of plastic materials is skyrocketing day by day [2]. Last year (2020), 367 million metric ton plastic produced globally whereas in 1950 this number was only 1.5 million metric tons. Among this large number of plastics produced each year, very few percent (9%) of plastic are being recycled [3] and rest of them are coming to environment (an average 50% for Europe used in land filling). Among total amount of plastic produced each year, 50% of them are used for single use purposes, but remains several hundred years in water [4,5]. This remaining have long term consequences on environment as it releases toxic chemicals such as dioxins, phthalates, vinyl chlorides, ethylene dichloride, lead, cadmium etc. These harmful chemicals can be found in blood and tissue of nearby all of us which can cause cancers, birth defects, impaired immunity, endocrine disruption and other ailments. Additionally, plastics reduce land fertility and threat marine lives [6].

Figure 1. Land diminishing effect of Traditional

Figure 2. Air polluting effect of traditional bricks

On the other hand, traditional bricks are universally used as building construction, civil engineering, and landscape design. By burning clay at high temperature for 10 to 40 hours traditional bricks are produced where heat leads to extremely strong ceramic bonds in the bricks [7,8]. Traditional bricks are associated with some problems, for instance, diminishing land, polluting air and higher price. The clay is collected from agricultural land, approximately 3 kilograms of soil or clay is required to produce 1 brick, as a result around 42000 acres of agricultural land is being diminished annually. If it continues, our food supply will be in danger very soon [9]. Moreover, several harmful chemicals emit from Brick kilns like sulphur dioxide, Nitrous oxide and other particular polutants that negatively affect environment [10]. Traditional bricks, additionally, require higher price in comparison to other manufacturing processes [11].

It is very important to overcome both the problems of plastic waste and

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traditional bricks to save the environment [12,13]. So, a problem solving technique is required which will solve both the issues of traditional bricks and plastic waste. By this technique, the waste will be converted into resource. Many solutions have already been given and are being practiced getting rid of the world from pollution and reduce brick manufacturing cost [14-19]. However, none of them showed manual brick manufacturing method using PE (polyethylene), PET (Polyethylene Terephthalate) and sand, and cost comparison with conventional bricks. This study focuses on the manual brick manufacturing process using different ratios of PE (polyethylene), PET (Polyethylene Terephthalate) and sand (silicon dioxide), then analyses and compares the compressive strength, water absorption percentage and manufacturing cost of developed bricks with conventional bricks.

Materials and Methodology

Polyester

It is generally known as Polyethylene Terephthalate (PET). Plastic materials are available beside us in the capital (Dhaka, Bangladesh). This material was taken from Tejgaon garbage storage, Dhaka shown in Figure 3.

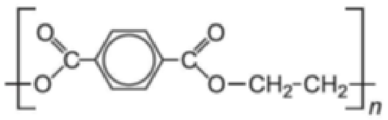

Figure 3. Polyester

Polyethylene

Figure 4 shows branched version of polyethylene is given below. It is also known as Low Density Polyethylene (LDPE). Which was collected from nearby Bangladesh University Textiles campus, Dhaka Bangladesh.

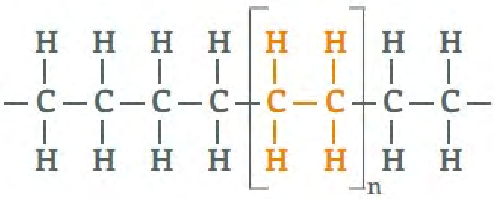

Figure 4. Molecular structure of PE

Sand

Sand was collected from Jamuna river (country's one of the biggest rivers) and was used in manufacturing bricks.

Apart from these materials, the following equipment and accessories were used in producing bricks such as wooden mould, gas burner, vessel, cover of the vessel and digital balance. Three samples were prepared with different ratios of PET (Polyethylene Terephthalate), Polyethylene (PE) and sand.

Manufacturing method

From Figures 5-9, Manual method was used while making the bricks with household equipment like simple burner, pot, spoon etc. that are commonly used in our daily life cooking rather machine type manufacturing method. In this experiment, after collecting plastics, proper washing was done to alleviate dirt, dust and harmful particles. After that, plastic sorting was done following the drying process. Here, sun drying process was used to remove the water from washed plastics. As river sand contains some dust and dirt, it is necessary to remove these unwanted particles by cleaning and drying. Fresh sand then mixed homogeneously with melted plastics according to their ratios. No heterogeneous mixing was done during bricks manufacturing process. Bricks can be produced at many sizes and shapes, to get the appropriate size and shape of brick appropriate wooden dice were made. The mixtures of sand and plastics, next, poured into the desirable dice carefully, and levelling and pressing were done perfectly to get exact shape and strength of the bricks. Then, it took 6-8 hours to cool the bricks, and by removing dice, bricks were taken.

Figure 5. Washing

Figure 6. Plastic Melting

Figure 7. Mixing

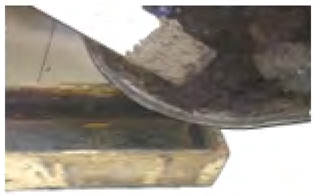

Figure 8. Pouring

Figure 9. Cooling

The developed bricks were obtained after the completion of the cooling process. In Table 1, it is mentioned about the three different samples having different ratios of PE, PET and sand. Same process was followed in all the three cases which are shown in Figures 10-12.

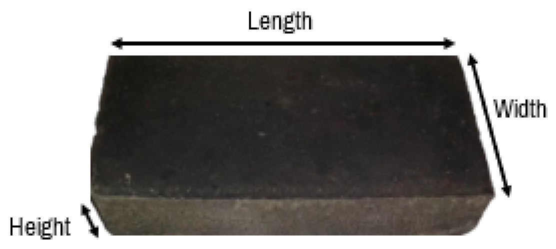

Figure 10. Sample A

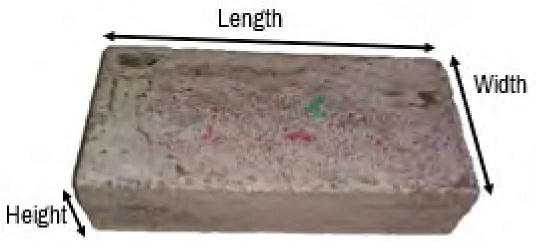

Figure 11. Sample B

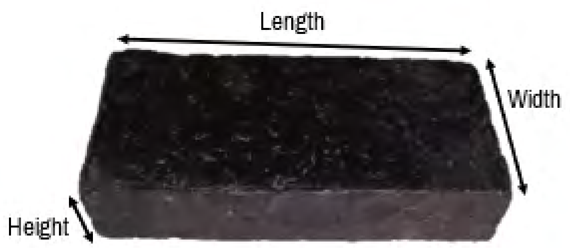

Figure 12. Sample C

Table 1. Different ratios of raw materials

Sample	PE	PET	Sand	Ratio
Sample A	1.9 kg	-	1.9 kg	PE: Sand (1:1)
Sample B	-	1.5 kg	1.7 kg	PET: Sand (15:17)
Sample C	1 kg	1 kg	0.8 kg	PE: PET: Sand (5:5:4)

Testing method

In this experiment, compressive strength of developed bricks was tested by Compressive Strength Tester Machine (Automatic) with BSTI (Bangladesh Standard and Testing Institution) standard (BDS 208: 2009, Specification of common building clay bricks) and Water Absorption Percentage was tested manually with the following steps [20]:

- The dry weight of all the samples was taken with the help of the digital balance
- After that, all the samples were kept in a bucket full of water for 7 days
- Then, all the samples were taken out, and outside surfaces were dried
- Following that, the weight of all the samples was taken with the help of the same balance
- The difference of the weight was expressed as the percentage of the dry weight

Result and Discussion

Dimension, Mass, Compressive Strength and Water Absorption (%) of developed bricks were investigated, then discussed, analyzed and interpreted. Three samples were developed from different ratios of PET, PE and sand. All the samples were not equal in their dimension and masses. Table 2 describes the dimension and mass of the developed bricks.

Table 2. Dimension and mass of developed bricks

Sample	Length	Width	Height	Mass
Sample A	25.2 cm	12.7 cm	6 cm	3.802kg
Sample B	25.4 cm	12.7 cm	6.35 cm	3.511 kg
Sample C	25 cm	12.5 cm	5.1 cm	2.836 kg

The result pointed that length and width of all the three samples are almost same. However, there are differences among the samples in height and mass. Sample A was made from polyethylene and sand is the heaviest. Sample B which was made from polyethylene terephthalate is having medium mass. At last, sample C which was made from polyethylene, sand and polyethylene terephthalate is the lightest of all the samples.

Table 3 shows the compressive strength of developed bricks. Compressive strength of all the developed samples is measured with the help of Compressive Strength Tester machine. This test was carried out in BSTI (Bangladesh Standards and Testing Institution), Tejgaon, Dhaka-1208, and BSTI standard (BDS 208: 2009, Specification of common building clay bricks) was followed during the testing of compressive strength of all the developed samples. It is found that the compressive strength of sample B is very high (15.67 MPa). The strength of sample C is higher than that of sample A. The crystalline part of PET polymer chain is high, which property helps to increase the compressive strength of the sample B. On the other hand, the amorphous part of PE polymer chain is high. As a result, the compressive strength of sample A is low. When both PE and PET are combined together, the compressive strength is improved to a small extent. But in all the cases, the compressive strength achieved is good enough to use in the probable application fields.

Table 3. Compressive strength of developed bricks

Sample	Sample A	Sample B	Sample C
Ratio	PE: Sand (1:1)	PET: Sand (15:17)	PE: PET: Sand (5:5:4)
In kg/cm2	85	172	92
In MPa	7.7	15.67	8.38

From Table 4, there are different types of classes in traditional bricks. The compressive strength of all the classes is not same. The range of compressive strength of traditional brick is between 3 MPa-12 MPa.

Table 4. Comprehensive strength of traditional brick

Brick Category	First class	Second class	Third class	Fourth class
In MPa	12	9	7	3

From Figure 13, it is understandable that, sample B (PET and sand) of developed brick is stronger than first class traditional brick, and which is around 30% much stiffer in caparison to first class traditional brick. However, rest of the two samples (A and C) are less strong than first class and second class traditional bricks. Moreover, all the experimental bricks are far better than third class and fourth class bricks in terms of compressive strength. Third class traditional brick is around 10% and 20% less strong than sample A (PE and sand) and sample C (PET, PE and sand) respectively. Whereas sample B is 5 times stronger, sample A is more than 2 times and sample C is less than 3 times stronger than fourth class traditional brick. Furthermore, second class traditional brick and sample C of experimental brick have almost same with considering their compressive strength. When the compressive strength of the traditional bricks is compared with the developed brick, the following graphical comparison is found.

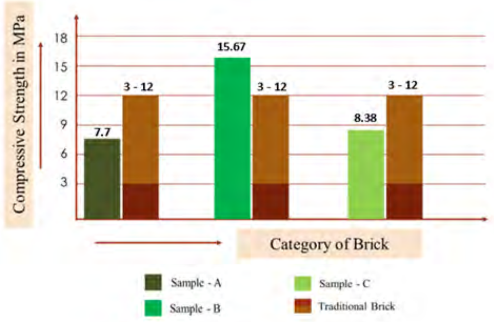

Figure 13. Comparison of compressive strength of developed and traditional brick

It is already mentioned that the water absorbency test was done manually. Table 5 shows that the water absorption of all the developed samples is very low. The water absorption percentage is the lowest for sample A (0.16%), and highest for sample B (2.2%). Sample C absorbs more water compares to sample A and less water in comparison with sample B.

Table 5. Water Absorption percentage of developed bricks

Sample	Sample A	Sample B	Sample C	Sample
Ratio	PE: Sand (1:1)	PET: Sand (15:17)	PE: PET: Sand (5:5:4)	Sample
Percentage (%)	0.16%	2.2%	0.39%	Sample

Figure 14 delineates the water absorption percentage of the traditional and developed bricks. The following formula was used to measure water absorption (%) of bricks. Water absorption %=(A-B)/B*100%, where, A is wet weight of brick, B is dry weight of brick. Traditional brick absorbs water approximately 264% more water than experimental sample B brick, and around 49 times and 19.5 times higher than sample A and C respectively. Higher the water absorption percentage, lower the durability of bricks [21]. As a result, the newly developed bricks will be more durable compared to the traditional bricks.

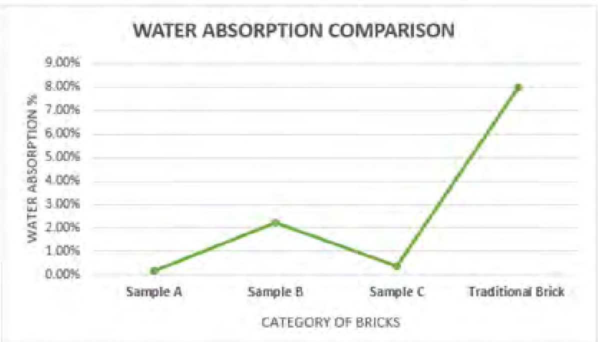

Figure 14. Comparison of water absorption % of developed and traditional brick

Cost analysis

To make the product commercially viable, it is essential to analyze the estimated manufacturing cost per piece. All the cost were analyzed in Bangladeshi TK (1 USD=around 85 TK) Considering the commercial prospect, Table 6 depicts the estimated cost per piece of developed bricks. This experiment, firstly, considered the cost of raw materials (Sand, PE, PET), following that added energy cost, labor cost and fixed cost. It is understandable from Table 6 that sample B is costly than other two developed bricks.

In comparison to traditional brick, Table 7 and Figure 15 delineate, all the three samples are cheaper than traditional one. Likewise, the cost of sample B and traditional brick are almost same 9.8 Tk and 10 Tk respectively with 5% markup price. However, considering mass production this small difference (0.2 Tk per piece) will go higher. In a nutshell, sample B is better than traditional brick considering cost.

As the developed bricks were manufactured from plastic materials and sand, it will have less environmental impact than traditional bricks. The current study showed an eco-friendly and sustainable brick manufacturing technique and also analyzed the cost with traditional brick. In a nutshell, considering compressive strength, water absorption, and cost, sample B is better than traditional brick.

Conclusion

This study focuses on thermoplastic waste reduction by manufacturing sustainable bricks, as recycling process is not widely used, and cheap bricks manufacturing process. It is clear that developed bricks especially sample B is far better than traditional bricks considering compressive strength, durability, cost and environmental impact. Moreover, this experiment indicates to the reduction of harmful chemicals to the environment such as greenhouse gases which are very common in traditional brick manufacturing process. This newly developed bricks manufacturing process is both environmentally and economically well. However, these developed bricks are flammable and UV rays can degrade plastics. If the developed bricks can be made flame resistant and UV protective, that would be a great invention in this arena.

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