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Innovative and Sustainable Application of PET Bottle a Green Construction Overview

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Abstract

Objectives: In this study an effort has been made to review the research works done on plastic pet bottles as a construction material replacing traditional bricks. **Methods/Statistical Analysis:** Construction activities impact a lot on the environment throughout the life cycle of the project. It is seen that a pet bottle fully filled and compacted with sand achieves a much higher compressive strength than that of a brick. On the other hand as the pet bottles can easily be collected from the waste, the cost of construction of this material is comparatively very less to that of the bricks. **Findings:** In this study several parameters like thermal study, sound insulation, light transmission, strength parameters, and structural stability have also been reviewed. **Applications:** The use of PET bottle is discussed and it can be used in constructing various structures which helps in sustainable development of the society.

Keywords: Brick, Compressive Strength, Eco-Brick, Green Construction, PET Bottle, Plastic, Waste

1. Introduction

In today's world, population is increasing day by day. As per a report population growth from the year 2005 to 2030 is estimated to grow from 1.1 billion to 1.47 billion[1]. With the increase in population the demand of construction industry as well as construction materials is also increasing day by day. As per a report by dgm events India, the size of construction industry in India in financial year 2013 was about US$ 153 billion, which increased to US$ 157 billion in financial year 2014[2]. As per a market research report 2014 by PWC it is estimated that the construction industry in India is likely to grow by a rate of 7% to 8%every year for next 10 years[2]. Another study from the year 2005 to 2030, building construction industry in India is likely to grow by a rate of 6.6% per year[3]. As the construction and development rate is increasing day by day, it is predicted that 70% of the wild life and natural habitat will be ruined by the year 2032[4,5]. Out of the total energy used and emission of greenhouse gases, almost one third is contributed by building only[6]. As per a report, growth of GHG emissions in India from the year 2005 to 2030 is likely to grow roughly 1.5 billion tonnes carbon dioxide equivalent to about 6.5 billion tones[7]. Carbon dioxide is one of the most important pollutants originated through human activities. As per a report, carbon dioxide contributed to almost 77% of the total greenhouse gas emission in the year 2004[8]. China is one of the major carbon dioxide emitter in the world since 2013[9]. In 2013 worlds total carbon emission was about 754.2 billion, in which chine contributed to about 14.4%[10]. Among the total energy consumed in china 16% is consumed by building materials[11]. It is assumed that, by the year 2050, building industry will contribute to about 52% of the total global carbon emission[12]. Bricks are one of the widely used construction materials in India. Most

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of the brick manufacturing units are run by small scale entrepreneurs may be in small industries, villages or event in cottages[3]. Indian brick industry is second largest producers of clay fired bricks, producing more than 10% of global production[13]. The brick manufacturing process in India is less energy efficient and generates a large amount of carbon dioxide to the atmosphere as coal is the main ingredient for firing bricks. On one hand the brick kiln establishment provides employment and adds to the prosperity of the village and on the other hand it also degrades the soil characteristics forcing the farmers to change their land use from agriculture to non-agriculture[14]. As per a study of solid clay bricks fired in clamps, the carbon footprints were estimated as 162g CO_2/kg, due to combustion of fuel (bagasse) and transportation of raw material[15]. Manufacturing process of bricks not only adds to the environmental pollution but also it offers high health hazards for brick kiln workers[16]. As per a study on brick kiln workers of Punjab province (Pakistan) it was found that, the people working in brick kilns are exposed to high level carcinogenic risk due to exposure to dust bound PAHs[16]. On the other hand as the plastic has become a part of our day to day life and its disposal is one of the major environmental problems, as the life of plastic product is very short and requirement is too high. Plastic is harmful to atmosphere in both production and disposal stages. As per a release by world watch institute in January 2015, the production of plastic has continued to rise for more than past 50 years[17]. The world's production of plastic was estimates to be around 250 million tons in the year 2009 which increased to about 299 million tons by the year 2013[17,18]. In India the growth of plastic industry is significant. In 10 years India has seen a considerable development of 290% in plastic production and 340% in per capita consumption[19]. As per a report, the plastic industry in India has expanded from 6 million tonnes per annum in FY 2008 to 8.5 million tonnes per annum in FY 2013[20]. As per reports released on the opening day of first United Nations Environment Assembly, the damage to marine ecosystem by the plastic disposal was about US$ 13 billion[21]. In the year 2012, 25 million tons of plastic waste in Europe were dumped in water streams[22,23]. For the overall growth of the economy of mankind a suitable waste management system is very necessary. In this study an effort has been made to review the various parameters of PET bottles to be consumed as a replacement of Traditional Bricks.

2. Background

PET or PETE (polyethylene terephthalate) is one of the most common types of plastics. Every country now aday is using the PET bottle system. As per a study, consumption of plastic in India may reach to 1006 Kilo Tons per Annum (KTA) by the year 2016-17[24]. Below given Figure 1 shows the rising trend of PET demand in India[24].

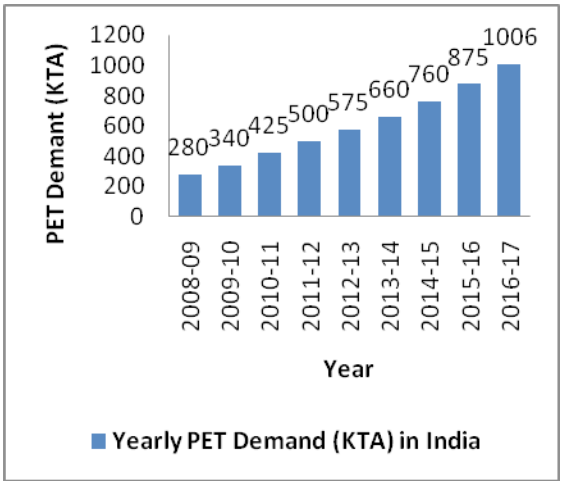


Figure 1. Pet bottle demand in India[24].

As per another study[25], India produces about 1.5MT of plastic waste every year. There are a number of polymers in plastic which are hard to recycle. Also the cost of recycling is too high. Hence very fewer industries take the pain of recycling plastic. Currently only 3.5% of plastics are being recycled[26]. The plastic waste recycled in India in the year 2006-2007 was 47% of the total plastic consumed[26]. Plastic waste management is done by several methods like land filling, mechanical recycling, biological recycling, and thermo chemical recycling etc[27]. The plastic present in environment does not decompose easily, it only fragments into pieces. The plastic present in the environment has an unfriendly impact on extensive variety of life forms[28]. The post consumed PET bottles are also sent for recycling and consumed in market in the form of films, packaging etc., but the percentage is less[29]. In the year 2011 only 51% of PET bottles in the market were being recycled[29]. Table1 shows the percentage Post- consumed PET recycled in Brazil, U.S. and Japan[30–34].

Table 1. Recycling rate of post-consumer PET

Year	Recycling Rate (%)		
	U.S.	Japan	Brazil
2006	23.5	75.1	51.3
2007	24.6	81.2	53.5
2008	27.0	82.2	54.8
2009	28.0	89.9	55.6
2010	29.1	83.5	55.8
2011	29.3	85.8	57.1
2012	30.8	85.0	58.9
2013	31.2	85.8	-
2014	31.0	82.6	-

On the other hand, as the demand of plastic is increasing day by day. So, more effective, ecological and economical methods are required for the disposal of plastic. As PET resins (with a higher IV) have high tensile strength[35]. In this study an effort has been made to use the PET bottles as sustainable construction materials to replace traditional bricks.

3. Study Elaborations

3.1 Construction Methodology

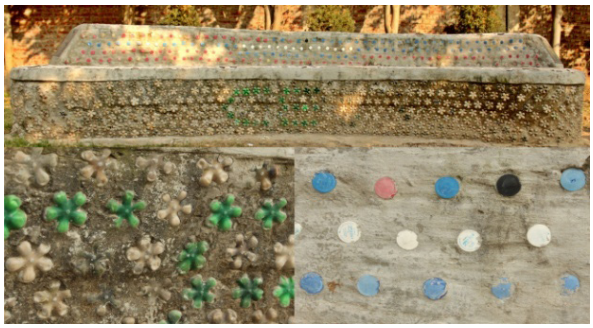
As shown in Figure 2, PET bottles are used in constructing a structure and the whole process is shown here.

- Collection of waste PET Bottles.
- Filling of Sand in PET Bottles.
- Laying and Binding of PET Bottles.
- Post Construction.

(a)

(b)

(c)



(d)

Figure 2. PET bottle construction process.

3.2 Materials Used

For construction of any structure some of the basic materials are required. The materials used in this study are as follows

- Cement- As binding material.
- Sand- For making mortar and filling of bottles.
- Nylon Rope- for binding of bottles.
- Water- For making mortar, curing etc.

3.3 Selection of Bottle

There are a number of varieties of bottles available in the market depending upon the usage, such as 300 ml, 500 ml, 1l, 1.5l, 2l etc. Various studies have used various types and sizes of PET bottles. The bottle to be selected should be in good shape and condition.

3.4 Strength Parameters

In a study in 2014[36], the PET bottles of size 500ml were used and tested for their compressive strength in a Denisone Compressive testing machine. The bottles were filled with household plastic waste to make them eco-bricks. As per the study, weights of all the samples of eco-bricks were in a range of 245g to 260g. The compressive strength results were also found good showing a resistance to compressive force up to 40KN.

As per another study in 2014[37], the plastic bottles were filled with soil and were tested for compressive strength. The results indicated that the average compressive strength resisted by various samples was 8.99MPa.

As per a study in 2016[38], the bottles were filled with fly ash and sand in various ratios and were tested for compressive strength. Best results were obtained by bottle sample filled with fly ash and sand in a ratio 2:1 resisting a compressive strength of 22,000kg.

As per an another study in 2016[39], a set of plastic bottles 105mm and 75 mm in diameter were collected and cut into 3 different heights of 200mm, 100mm and 50mm. the bottles were then perforated with holes of 10mm diameter on a distance 20mm center to center around the circumference. The plastic bottles so formed were wrapped with jute geotextile from inside and filled with fly ash and some with aggregate of varying proportions. All the samples were tested for compressive load. The results indicated that the samples can resist a high compressive pressure up to 4000 KPa to 5000 KPa.

3.5 Sound Insulation

As per a study[36] the sound insulation parameters of Eco-bricks were investigated. The calculation of sound index is not possible unless an entire room of eco bricks is prepared. The study was conducted to calculate sound reduction index. A comparison of eco-bricks, concrete blocks and sand bricks was done. Results indicated that the eco-bricks have lowest sound resistance index as compared to sand bricks and concrete blocks.

3.6 Light Transmission

As per an investigation[36] carried out on eco bricks it was observed that very low amount of light passes from the brick which is not even visible to human eye.

3.7 Structural Wall Stability

A study[40] was conducted on a wall of 3m height and 300mm thickness. The wall was constructed with air filled bottles and tested for structural stability. The results indicated that the wall resists almost 50% less load as compared to individual block, may be due to mortar interlocking.

3.8 Thermal Strength

A study[41] was conducted on a small prototype green house built by using sand filled plastic bottles as bricks. The study indicated that indoor and outdoor temperature difference when compared with plastic bottle green house and a normal brick house remains more or less same. Both the houses have not achieved thermal comfort zone as the temperature ranges 30°C to 34°C for green house and 29°C to 34°C for normal brick house.

3.9 Cost Analysis

The cost of PET bottle green house will always be less than traditional brick house. As the bottles to be used for construction are available in abundance and are free of cost. On the other hand a single traditional brick will cost nearly Rs.5.50/-. Rest of the building materials used in the construction of both the traditional house and green house are nearly same and will have a very less effect on the cost difference.

4. Conclusion

It can be concluded that many research work has been carried out on use of PET bottles in construction as the Eco-Bricks i.e., the PET bottles filled with sand, soil, fly-ash or any other material like household plastic waste when well compacted can be used as a building material replacing traditional bricks. The strength parameters of filled plastic bottles are on a higher end as compared to traditional bricks. The eco-bricks are light in weight and possess same thermal properties as of traditional bricks. The eco-bricks have high sound reduction index as compared to concrete blocks. Eco-bricks also do not permit light to pass through then as when seen by naked eyes. It is the most effective and economical way of using post consumed PET bottles.

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