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Utilization of PET Waste in Plastic Bricks, Flexible Pavement & as Alternative Constructional Material - A review

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Abstract

The 21ST century is facing a serious situation in waste management, especially Plastic waste. Plastic has many advantages but with it comes with many problems too. Being non-degradable for years, it has become a global problem in recycling it. PET being one of the most common consumer plastic as it is used to build many basic and day to day life products like bottles, containers for food industry and beverage industry. PET waste has become major environmental issue due to its various properties like non-biodegradability and gases released on incineration. Therefore PET waste has to be utilized and recycled efficiently. This paper provides a review of different products such as Plastic bricks, Flexible pavement and Plastic bottles as a constructional block which can effectively use PET waste as an alternating material.

Keywords: Plastic bricks; Plastic pavement; PET (Polyethylene Terephthalate); MSW (Municipal Solid Waste)

1. INTRODUCTION

The word plastic means any material which is made of synthetic or organic compound which has malleable properties. The major features which play a big role in the usage of plastic are malleable, durable, light weight, impervious to water and low cost [1]. They have replaced traditional materials which were used in manufacturing like wood, metals, paper, stone etc. This makes plastic a perfect and effective raw material for production. Plastic has revolutionized each industry like automobile, Medical, Electronics, Toy, Manufacturing and many more [2]. Thousands of polymers exist in nature and the most abundant one is cellulose. In 1861 Thomas Graham was the first one to observe that when organic compounds are dissolved in solutions they leave behind a sticky solution, he named them colloids which means glue in Greek. In 1870 John Hyatt used chemically modified Cellulose to produce celluloid. Around 1907 Leo Baekeland with two chemicals phenol and formaldehyde created the first synthetic man made material. He named it Bakelite. This opened the gates for the further growth of synthetic materials [3]. Plastic has many advantages but the problem which has risen is that after the usage of plastic it is thrown away. Being non degradable for years, Plastic recycling has become a global problem. Being non degradable it is causing harm to the nature in many ways. It is causing Land pollution where plastics are dumped. Harming marine ecosystem as plastic are just dumped into the oceans. It also Air pollution when incinerated. Burning of plastic release toxic gases like Dioxins, Furans, Mercury and Polychlorinated Biphenyls. Burning of PVC liberates halogens hazardous to atmospheres which result into adverse effects on climate. Humans and Vegetation [1]. The plastic production globally has gone from 2 Million tonne in 1950 to 380 Million tonne in 2015 with cumulative of 7800 Million tonne. Out of which 1/3 is in use and the rest is waste. Study shows only 9% of this is recycled and 12% have been incinerated [4].

Indian lone produces around 40 Million tonne of Urban Municipal Solid Waste (MSW) every year. Majority of this waste is sent to unsanitary landfill sites openly dumped due to weak infrastructure of recycling plastic [5] [6]. The major reason for failures is rapid urbanization which grew by a factor of 8.9 in Mumbai, 13.6 in Bangalore, 20.4 in Delhi from 1950 to 2015 and exponential population growth in India [7]. Attempts to improve the present condition are being done by bringing the MSW Management and Handling Rules 2000 and Solid Waste Management (SWM) Rules 2016. India's MSW varies highly among urban and rural areas [8]. Municipal Solid Waste typically includes degradable (paper, Textile, Food waste, straw and yard waste), partially degradable (wood, disposable napkins, sludge) and non-degradable materials (leather, plastics, rubbers, metals, ash from fuel, dust and electronic waste) [9] [10].

One area of growing interest in India is Waste to energy (WTE) market which deals with the energy recovery from MSW. WTE not only recycles plastic but also has a high potential to be valuable renewable energy source which is feasible as well as environmentally stable [11] [12] [13]. The World Energy Council reported that the Asia-Pacific region (mainly comprising of India and China) has the fastest growing market size in terms of WTE [14]. The Government of India says that non-recyclable waste with calorific value of 1500 kcal/kg must be used for energy recovery or in the preparation of refuse-derived fuel (RDF). The market potential of WTE is estimated to be 1.5 GW in India and only 2% of this total has been realized [15] [16]. There are various methods available at present by which PET waste is been utilized like depolymerisation of PET bottles in to unsaturated polymer resign [17] [18] [19] [20], Usage of PET fibre as concrete reinforcement [21] [22] [23] [24] & Using Plastic waste as a replacement to partial aggregate [25] [26] [27]. This paper provides different ways by which PET waste can be used effectively, the ways are shown in Figure 1.

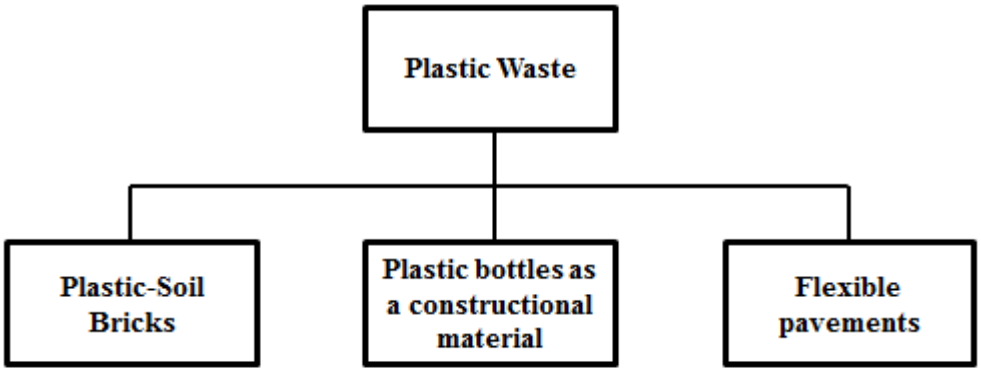

Figure 1 Applications of PET waste

2. PLASTIC-SOIL BRICKS

K.M. Nashimath et al. [28] has carried out experimental investigation of variation in plastic percentage (65%, 75%, 85%) by weight of soil and percentage change in bitumen (4%, 8%, 12%). Overall 9 bricks were made and air dried for 24 hours. Bricks mere made in size of 20cm*10cm*10cm. Compressive and water absorption test were conducted. Table 1 shows the compressive strength of different plastic bricks with different proportions of plastic content and bitumen content. They concluded that as plastic content increased, compressive strength increased and optimum results were obtained at 85% plastic and 12% bitumen with 6.56 N/mm^2 compressive strength which is comparable to 2nd class bricks.

Table 1. Compressive strength

Percentage of Plastic	Percentage of Bitumen	Compressive strength in (N/mm^2)
65%	4%	3.56 N/mm^2
	8%	4.15 N/mm^2
	12%	4.47 N/mm^2
75%	4%	5.18 N/mm^2
	8%	4.68 N/mm^2
	12%	5.67 N/mm^2
85%	4%	6.42 N/mm^2
	8%	4.69 N/mm^2
	12%	6.56 N/mm^2

G. Miruthula et al. [29] has carried out experimental investigation of variation in Plastic percentage (50 %, 60%, 70%, 75%, and 80%) and constant bitumen percentage 2%. Bricks were made in size of 23cm*10cm*8cm*. Overall 5 bricks were made. The bricks were air cooled for 24 hours before test. Compressive strength test and water absorption test were conducted. Water absorption by the bricks was negligible. They concluded that brick with 2 % bitumen and 60% plastic content has optimum results with 11.01 N/mm^2 compressive strength more than 2nd and 3rd class bricks.

Puttaraj Mallikarjun Hiremath et al. [30] have carried experimental investigation of variation in percentage of plastic waste (PET) by weight of soil (65%, 70%, 75%, and 80%) at constant bitumen, 2%. They also studied variation in compressive strength by change in % of bitumen (2%, 5%, and 10%). For each proportion of plastic waste they constructed 3 bricks with different proportions of bitumen (2%, 5%, and 10%) by weight of soil. Overall 12 bricks were made of different proportions. The brick was made from a mould of size 20cm*10cm*10cm. The bricks were removed from the mould and air dried for 24 hours. Compressive strength test and water absorption test were conducted. From the experiment they concluded that plastic soil brick with 70% of plastic waste and 2% bitumen by weight of soil has compressive strength of 8.16N/mm^2 which is quite more than the laterite stone. It also absorbs less water about 0.9534% compared to 14.58% of laterite stone. The compressive strength of bricks increased when % of bitumen increased up to 5%, 10N/mm^2 (70% plastic waste) but decreased on further increasing of bitumen.

3. PLASTIC BOTTLE AS A CONSTRUCTION COMPONENT

A.M.H Mansour et al. [31] has carried out experiment both thermally and structurally to replace concrete block by plastic bottles (PET) as a sustainable construction material. They used average PET bottles of length 30cm and Diameter of 9 cm. The mean skin thickness was about 0.5 mm. Test were conducted using different specimen inside the bottle like dry sand, Saturated sand and air. The weight of different bottles after filling the specimen is 0.33 N with air, 22.45 N with dry sand and 32.54 N with saturated sand. A Total of 9 specimens of 3 each air, Dry sand and saturated sand was created. Each block was made of 30cm*30cm*30cm containing bottles in such a way that they interlock each other. The block then was filled with mortar made of specific amount of proportion of sand, cement and water. Figure 2 shows the arrangement of the plastic bottles and addition of mortar into the mould. The block then was left for a day in the mold and then was taken out and cured by immersion in a water tank for 27 days. Compressive strength was found out to be 670 KN/m^2 which is way less than 3670 KN/m^2 of traditional concrete blocks. The thermal test showed that the plastic bottle block showed great thermal resistance when simulation where performed in ECOTECH software under Abu Dhabi conditions. By the experiments they concluded that air filled bottles cannot be used to make conventional walls but partition walls or roof slabs with a factor of safety of 5.8.

Figure 2 Arrangement of bottles in the block (filled with different sands and air)

M.V Shoubi et al. [32] they have proposed a new technique to use plastic bottles as an alternative of traditional building materials. They have proposed Eco-Tec technique introduced by Andrea Froese. In this technique bottles are kept in a specific way simultaneously over each other. The bottles are filled with different specimens; Front and rear end are filled by sand and gravels while the middle part is filled by cork or wood particles. Figure 3 shows the arrangement of plastic bottles in the way Andrea Froese has mentioned. They concluded that this arrangement of plastic bottles has upper hand from the conventional walls in terms of cost, thermal stability and shock absorbing capacity.

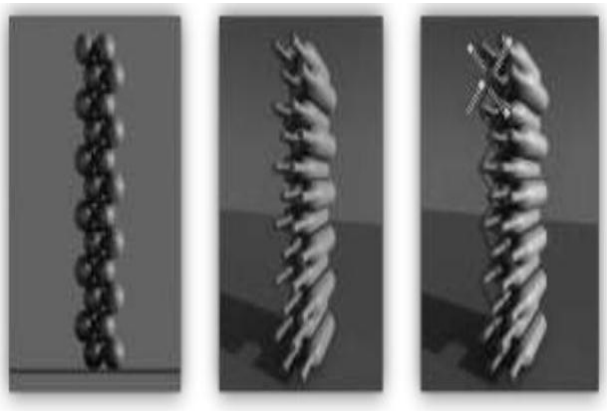

Figure 3. Plastic bottles arrangement

Z. Muyen et al. [33] carried out experiment investigation by making plastic bottles (500mL) concrete block each with 9 and 12 bottles placed in 3 layers above each other. The block was made of size 25.4cm*25.4cm*25.4cm. Firstly the bottles were washed and then filled with fine sand. A 2cm thick cement mortar was placed firstly given 20 blows. Then first player of plastic bottles were arranged in horizontal layer comprising of 3 and 4 bottles for arrangement of 9 & 12 bottles in 3 layers as shown in the Figure 4 **&** Figure 5**.** After that once again a 2 cm thick layer of cement mortar was placed and given blows. Same process was used unless whole block was made. The compressive strength of 9 Bottles arrangement was found to be 35 MPa whereas 12 bottles was found to be 33.7 MPa. They concluded that this can be a great alternate in low income countries like Bangladesh and can be a sustainable alternative constructional material.

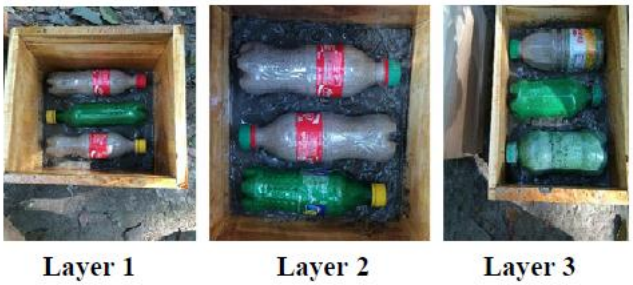

Figure 4. 9 Bottles arranged in 3 layers

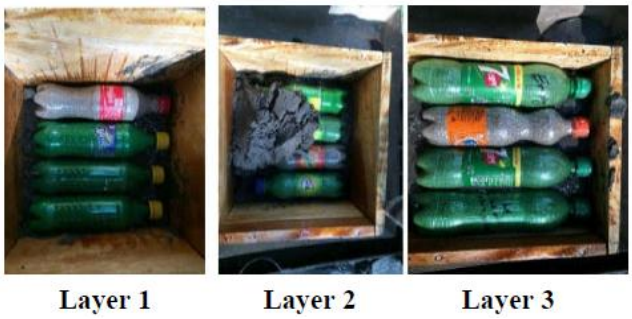

Figure 5. 12 Bottles arranged in 3 layers

4. PLASTIC IN FLEXIBLE PAVEMENTS

S.R. Unde et al. [34] has carried experimental investigation of use of plastic waste in varying percentage(6%, 8%,10%) by weight replacing bitumen content on the physical properties of the modified pavement. Plastic waste (PE, PET, PP) were shredded in size of 2.36 mm and 4.75 mm, PVC waste was removed. Then the aggregate mixture was heated at 165*C and

bitumen was heated at 160*C. Aggregate mix and plastic waste were added in mixing chamber for 30-45 seconds and then were placed on road with the Hot bitumen. Test like aggregate Impact value, aggregate crushing value and Los Angeles Abrasion test were conducted for aggregate mix with various proportion of plastic waste (6%, 8%, and 10%). They concluded that Aggregate Impact value was reduced to 22% at Plastic waste at 10% which increases the toughness of the aggregate. They found that at 8-10% of plastic waste when mixed with aggregate and bitumen provides optimum results.

S.B. Neha et al. [35] has carried experimental investigation of use of plastic waste in varying percentage (5%, 10%, and 15%) by weight replacing bitumen content. Suitable aggregate was selected and Bitumen of 60/70 grade was used. The process of mixing the aggregate and plastic waste was done by shredding and placing plastic over hot aggregate which makes a good coating of plastic over the mixture. The process adopted for the process was Dry process. After making the blends they were kept for water bath for at least 24 hours. Various test like water absorption test, Aggregate Impact value test, and Los Angeles Abrasion Value were performed for Aggregate mix with varying percentage of plastic waste (5%, 10%, and 15%). They concluded that plastic waste increase the properties of the aggregate. 10% of plastic provides optimum results. The pavement with 10% plastic was found better than conventional flexible pavements.

5. CONCLUSION

Plastic waste and its recycling has become a problem in not only in India but globally. Plastic is need of the hour and its usage cannot be stopped in manufacturing sector. The Waste to energy segment in India has huge potential which has not yet been fully utilized. But with Efficient usage of Plastic waste in different products, Plastic waste can be utilized efficiently. It can be concluded that Plastic pavement with varying percentage plastic is better than the traditional flexible pavements in India. Its performance and life cycles are more and required low maintenance. The plastic bricks which are made from Plastic bottles has compressive strength of a 2nd level brick and can be used effectively everywhere in construction. The usage of plastic bottles as a construction material provides compressive strength lows compared to concrete blocks but has enough strength that it can be used to build partition walls and roof slabs from it. With higher thermal resistance they can also be used as insulators. Plastic bottles walls also shows better shock absorbing capacity towards abrupt shock loads which performs better in situation like earthquakes. Thus these all methods can be adopted to use plastic waste in different sectors and products which can lead to efficient and effective use of plastic waste.

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