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Reuse of Various Types of Plastic Waste as Different Construction Material: A Review

Ajeet Verma[1], Hans Pal [2]
[1]*M.TECH, Environmental Engineering, Institute of Engineering and Technology, Lucknow, U.P, India*
[2]*Assistant Professor, Civil Engineering Department, Institute of Engineering and Technology, Lucknow, U.P, India*

Abstract: Plastic waste is a major problem in present world. Being lightweight, strong, moldable, and convenient to manufacture, plastics find use in many products. Consequently, plastic consumption has grown steadily over the last 50 years. Solid waste has plastic waste as its major constituent. A large stream of research has studied the performance of waste plastics impregnated concrete, reporting multiple benefits and advocating its use in construction works. There are different types of plastic present in the waste and each having the different potential of its usage as construction material. In this paper we will be discussing about the manufacturing of bricks using crushed plastic as aggregate, variation in the strength as the plastic content changes. Different study shows various types of plastic waste used as construction material. Along with the compressive strength the variation on thermal property and water absorbtion is also seen.

Keywords: Plastic Waste, Solid Waste, Construction Material, Reuse plastic, Crushed Plastic, E-Waste.

I. INTRODUCTION

Due to urbanization and modernization the high volume of wastes generated and disposed of annually. There are various activities by human, in manufacturing of product and after utilization that generate huge amount of waste. Yet, these wastes are mostly managed by disposing them into landfills. However, high cost is associated with landfilling, can be a major constraint to the management of these wastes. The volume of solid wastes generated keep on increasing year by year, whereas only a limited amount is recycled and landfilled, and a large amount of wastes such as plastic wastes are deposited directly or indirectly to the water bodies. One of the major solid wastes generated in huge quantities and being of a high threat to the sustainability of our planet is plastic wastes. It has been reported that damage occurs to ecology, economy, and aesthetics when plastic debris enters into water bodies. About 300 million metric tons of plastic wastes is estimated to be generated annually . Large quantities of plastic wastes are generated all over the world, because of its large application, such as in automotive, manufacturing, packaging, and healthcare. The high cost and energy associated with the landfilling process have resulted in wastes being disposed in water bodies. The low biodegradability of plastic is a huge limitation on its recyclability and disposal into the environment. Therefore, finding applications where plastic wastes can be used will proffer a sustainable way to its management. In addition, reuse and recycling of plastic wastes is more effective when compared to landfilling and incineration. Many attempts such as source reduction, reuse and landfilling have been done to reduce the critical amount of PW generated annually. However, due to rapid developments, there has been a persistent increase in the amount of plastic waste generated. Recycling plastic waste will prevent contamination of the environment and will add value to the plastic waste by creating an option to incorporate these materials for different applications such as in construction. The opportunity to use these plastic waste for construction applications will not only conserve the marine environment but reduces the overall environmental threat due to the production of these plastic. The possible use of plastic waste for construction applications will help the construction industry to achieve its objectives sustainibly. Significant reduction in energy consumption and carbon emission will ensue when the plastic waste is reused as the amount of new plastic processed and produced will be reduce. Several types of plastic wastes exist, and the most common ones in waste streams are polyethylene and Polyethylene terephthalate . As recycling of plastic waste has been found to be effective, there are different ways to recycle these wastes which have been extensively explored by the packaging industry, though , its use in the construction industry is less common. The construction industry is a promising sector where plastic waste can be used for various applications, mainly because it is the huge industry in different economies and the highest consumer of raw materials. Plastic waste can be used as a civil construction material in the form of aggregate in cementitious and asphalt mixtures, filler, insulation, etc. However, despite the huge potential for the application of plastic waste in construction, its use and development are still very limited. Therefore, this paper covers the current application of PW for various construction applications.

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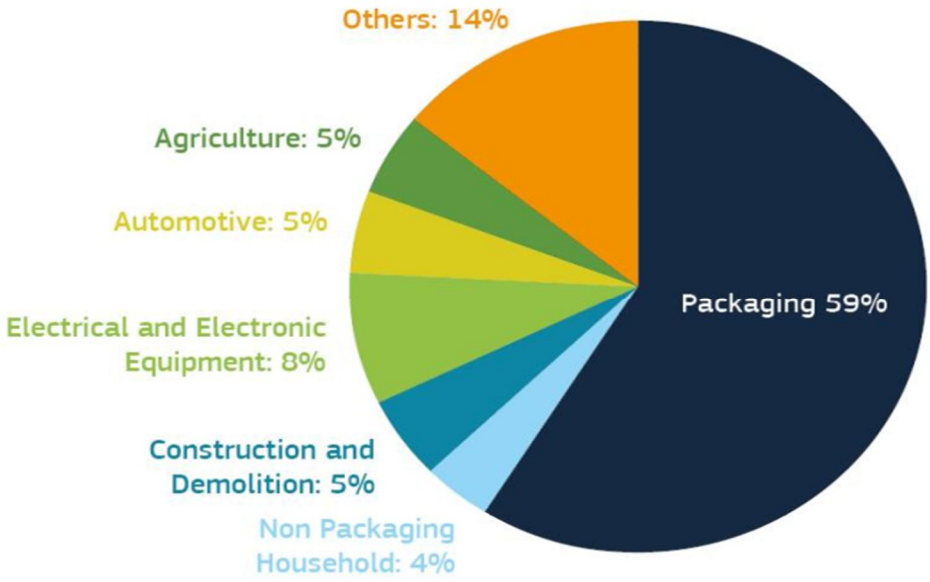

Fig 1- Sources of Plastic Waste.(Source:- eur-lex.europa.eu)

II. STUDY OF METHODOLOGY ADOPTED

Every plastic container contains the 'resin identification code' (RIC) which contains numbers ranging from 1 to 7 in a triangle that indicates its suitability to recycle the plastic used. These symbols indicate the chemical constituents, toxicity, and the possibility of leaching. The major materials classified under these numbers are: (1) Polyethylene Terephthalate (PET), (2) High-Density Polyethylene (HDPE), (3) Poly Vinyl Chloride (PVC), (4) Low Density Polyethylene (LDPE), (5) Polypropylene (PP), (6) Polystyrene, and (7) other miscellaneous resins including polycarbonate. While plastic with symbols 1, 2, 4, and 5 can be safely recycled, those with symbols 3, 6 and 7 are relatively unsafe for recycling; it may be noted that the plastic with symbol 7 is unsafe.

Fig 2- Symbols For Resin Identification Code.(Source:- www.guides.stopwaste.org)

A good option to recycle waste plastics is to convert them into shorter molecule liquid or gas through pyrolysis. There are many literature which evolved over the years delineating processes and catalysts for pyrolysis of different plastic materials with various efficiency levels. Many of the successful pieces of research have been reported to convert plastics into oil and biochar with different conversion rate. Thermoplastic elastomer made of used thermoplastic and used rubber shows improved tensile strength as also improved thermal stability. However, plastics with 'resin identification code' (RIC) of 3, 6, and 7 are less suitable for recasting, though the process is simple, but is quite expensive and unsafe for health. Large-scale use of recycled plastic in eco-friendly construction material, such as bricks and concrete may lead to sustainable management of waste plastic material. The commercial application of the waste plastic as construction material is very less at present time.

In study by M.K. Mondal et al.[2]they constructed sample blocks of 76mm cube were prepared using different compositions with varying waste plastic contents from 0% (control) to 10% by weight. All samples contained 15% ordinary Portland cement (OPC), 15% fly ash and rest sand of less than 2mm size on a dry weight basis, and water of 25% of the dry mix. The process only used self-compaction with no mechanical intervention. The blocks were removed from the mold after 24 hr, and were cured under water for 28 days. Two batches of the samples were baked at 90 °C and 110 °C for two hours. Various mechanical tests were conducted including compressive strength, water absorption rate.

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III. MATERIALS AND EQUIPMENT

The construction industry serves as a backbone of any country's economy, any improvement over it not only improve its economic condition but also will improve the sustainability of construction processes and practices. The sustainable use of plastic wastes for construction purposes is very beneficial economically as well as environmentally. Therefore, the possible use of waste materials provides economic and environment benefits. The sustainable use of plastic waste in construction applications will significantly reduce the amount of plastic wastes disposed into the marine environment and will reduce the demand of alternative materials to meet the demand of the construction industry. However, in order to use plastic waste for construction purposes, it has to satisfy both the mechanical and durability properties of the desired application. In addition to the performance of plastic waste as a construction material, it should be cost-effective and sustainable to enhance its use over other types of materials. Waste plastic bags, which are non-biodegradable, have been recycled for the production of different materials such as floor and wall tiles with lesser flammability and enhanced tensile strength. It has been seen that plastic bags can be developed into a lightweight and highly durable products.

Different studies shows different behavior of the plastic waste as construction material depending upon the type of plastic and percentage of waste plastic added. In P.O. Awoyera et al.[1] the study shows various future usage of the plastic waste in construction industry. The study also shows the comparison of sorting, recycling, reprocessing potential of different types of plastics. In study by S. Needhidasan et al.[3] the potential of using the electronic waste in contcrete. E-waste plastics is used as coarse aggregates by replacing the coarse aggregates in a concrete by volume 0%, 12%, 17% and 22% with super plasticizer and the results are analyzed. The specimens were moulded in standard cubes and cylindrical shape and there compressive strength is checked. In the study by Yat Choy Wong et al.[4] on concrete footpath with recycled plastic and crushed glass as filler materials it has been showed that 10% RPW and 10% RCG of the concrete design mix has the potential to be incorporated in concrete footpaths as a sustainable material and this will lead to a significant reduction of the amount of plastic and glass wastes ended up in landfills.

Fig 2- Brick specimen made up of waste plastic. (Source:- www.expertskiphire.co.uk)

Beside from the application of plastic wastes for construction purposes, there are other products that have been developed for general engineering and indoor use[1].

A. Base And Subbase For Road Constructions

The use of plastic waste as a replacement for aggregate used in base and subbase construction for pavements, it has been found to improve the shear, stiffness and bearing capacity of the pavement. A similar observation was also reported by Choudhari et al. and Jha et al.[8] where they observed the properties in pavement reinforced with recycled plastic strips. Arulrajah et al.[7] also explored the viability of using plastic waste granules alongside demolition wastes as blends for road construction. Their study showed that the incorporation of plastic waste lowers the stiffness, bearing capacity and resilient modulus of the blends, however, the acceptable performance was still achieved. The reduction in the properties of the blends was due to the physical properties of the plastic waste (i.e. their smooth surface).

B. Components In Asphalt

Similar to the use of plastic waste as aggregate in cementitious composites, it can also be used into asphalt mixtures . The use of plastic waste as aggregate in asphalt has been found to have improve the skid and crack resistance of the pavement. The increased performance in both studies including plastic waste can be assign to the improved resistance of the matrix with the incorporation of the plastic waste. However, 5% was concluded to be the optimum amount of plastic waste that can be assimilate into asphalt mixtures without any detrimental effect on its viscosity.

In addition, there is a reduction in traffic noise on pavements made with asphalt mixtures including recycled plastic wastes. The lower traffic noise associated with asphalt mixes having plastic waste can be due to the ductile behaviour of the matrix coupled with high energy absorption. With several types of wastes obtain from different plastic types, the use of low-density polyethylene (LDPE) and high-density polyethylene (HDPE) plastics have been found to be the most promising in asphalt mixtures compared to other types. Nevertheless, studies have been carried out to investigate the use of polyethylene terephthalate (PET) plastic wastes as aggregates in asphalt mixtures[10].

C. Filler

Another prospect for the use of PW for construction applications is to be used as fillers. The use of PW as fillers is one of the most effective and easy ways to use it for application purposes as their application is non-dependent on the chemical properties of the RPW. This application is similar to how the RPW is used in cementitious composites and asphalt mixtures.

D. Wood Replacement

Few studies have been able to produce a replacement for wood from plastic waste. The plastic waste used was from different plastics and after being recycled can be used like wood (i.e. cut, sawn, nailed, etc.). In addition to their wood-like behaviour, they are also more durable than the wood in terms of their weather, biological and saltwater resistance. However, the high cost associated with the recycling of many types of plastic coupled with its bulky nature limits its application. Nevertheless, these types of plastic waste are suitable for railroad ties, boat docks, benches, etc. It is worth mentioning that this type of wood replacement has also been referred to as plastic lumber.

E. Door Panels

Plastic waste can also be combined with wood to produce an eco-friendly door panel. These eco-friendly door panel can be obtained by combining plastic waste in pellets or powder form with cellulose fibre or wood flour to form a thermoformable wood plastic matrix that can be used for door panels.

F. Insulation Material

Insulations materials are very important components of buildings. However, the economic and sustainability constraints related to conventional insulation materials has called for a need to use alternate materials as an insulation materials. One of the possible greener alternative material that can be used as insulating material is recycled plastic. Particularly, plastic waste in the form of expanded polystyrene (can be incorporated as insulation material during the construction process. However, the low density of expanded polystyrene coupled with its fire safety has limited the capability to recycle and transport the recycled materials.

G. Walls And Bricks

Plastic waste can also be used as a replacement for conventional block, brick or wood walls. These plastic walls are made by placing recycled plastics in heat moulds and pressing the moulds together in different patterns to form blocks. However, it is worth mentioning that these types of walls cannot be used for load-bearing applications but are suitable for wall construction applications such as partition walls,or as parapet wall. In contrast to conventional bricks, waste plastic bottles can be arranged in a similar format as bricks and used for walls. The waste bottles are connected to each other by inserting the bottleneck of each bottle in the base of another bottle. However, similar to the plastic walls, plastic bricks can be used as a structural material to a limited extent – albeit with a low strength. Similarly, construction can also be made using plastic wastes made up of LDPE[9].

IV. RESULTS

On reviewing different research paper the following result is obtained.

A. The compressive strengths observed in the plastic-consisting bricks in the study compare well with that of traditional clay bricks. Many studies are mostly related to various types of waste plastics impregnated concrete. The mechanical properties observed in the plastic impregnated bricks in the study compare favorably with the of standard fired clay bricks and are found to be more superior as compared to those of fly ash bricks. For example, the compressive strength of fired clay bricks is observed to vary between 15 and 20 MPa and that of fly ash bricks between 11 and 19 MPa. The bricks with 10% waste plastic demonstrate compressive strength of 17 MPa and are of higher thermal resistance, while the density is significantly lower.[2]

B. It has been found that the optimum strength of concrete was gained at 17% of E-waste plastic replacement in concrete. The E-waste plastics were chipped to 10–20 mm size without any metals were used in this experimental study[3].

C. The use of plastic waste in asphalt does not alter its properties much. The use of plastic waste as insulating material and wood replacement is not only a better substitute to the conventional material but also having better properties.

V. CONCLUSIONS

These conclusions can be concluded from the above study:-

A. The use of plastic waste as construction material not only solve the problem of disposal of solid waste but also provides a better substitute to the conventional material and products.

B. The bricks made after adding the plastic waste in limited quatity will not alter the property of the brick

C. The use of plastic waste as construction material solve the problem of disposing plastic waste for longer time period since the life of building is larger as compare to any other product .

D. The use of plastic waste as wood replacement will bring down the dependency of construction industry on timber, ultimately saving plants.

E. The reuse of plastic waste will not only lead to the revenue generation but also helps in reducing the exploitation of resources.

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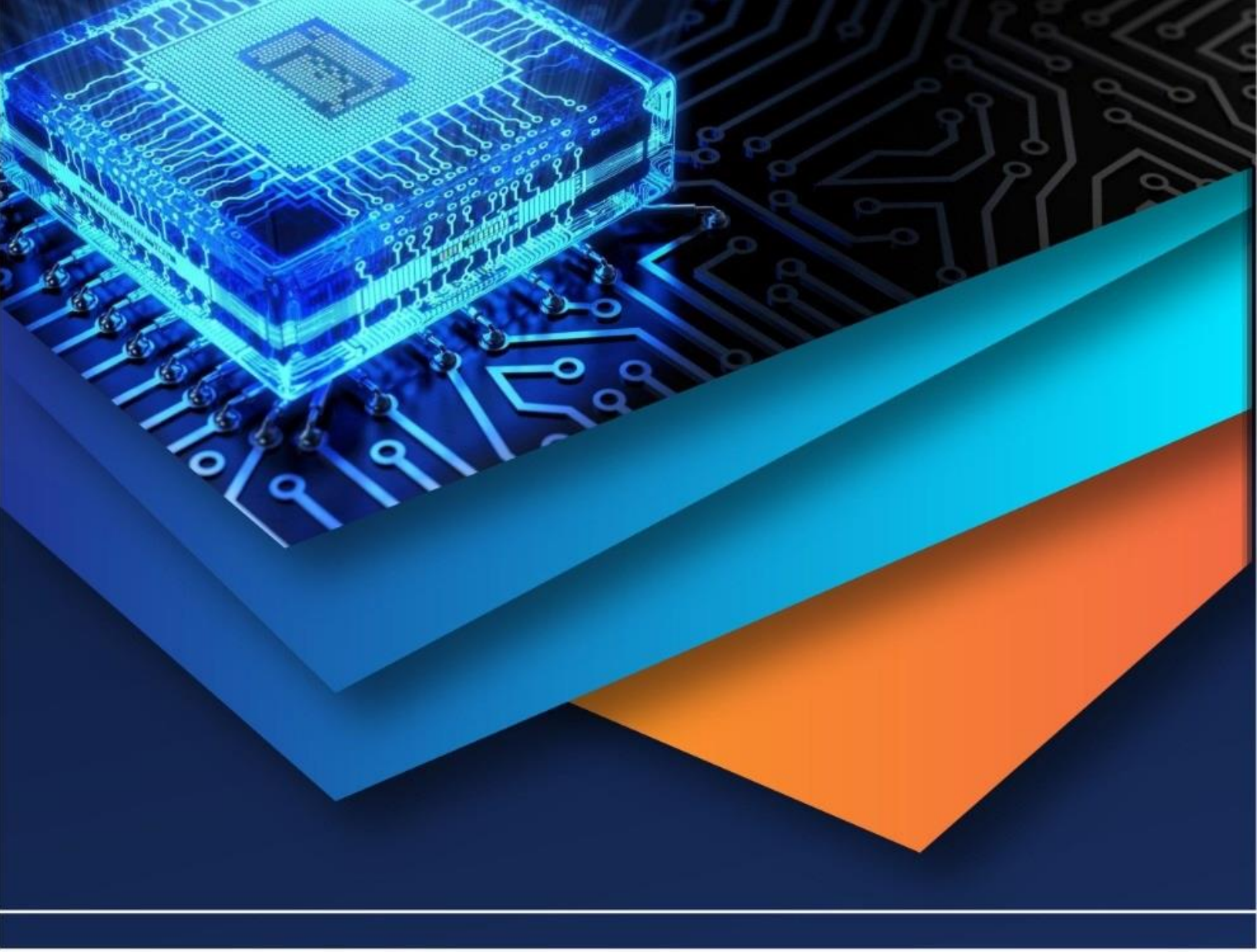

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