Reviewing the Influence of Recycled Plastic in Construction Industry

Manisha Sharma[1], Tanpreet Singh[2] , Jaspal Singh[3], Sahibdeep Singh Setia[4]
[1,2]GNDEC, Ludhiana, Punjab,
[3]PAU, Ludhiana,Punjab,
[4]Dr B R Ambedkar NIT, Jalandhar
Email: [1]37manisha.s@gmail.com, [2]civil6011@gmail.com
[3]jaspalsingh@pau.edu,[4]sahibdeepss.ce.20@nitj.ac.in

***Abstract*—In today's world, synthetic polymer, natural polymers and modified natural polymer are widely used and contribute significantly to the standard of life and serving to boost the living standard within the world. Plastic pollution is described as any plastic that ends up in the atmosphere, including bottles and bags to less visible sources such as teabags and clothing. Concrete, being most used building material and often made from nonrenewable natural resource. Use of plastic waste is an opportunity to boost the industry's sustainability. This paper presents the overview of work carried out on the use of common type of plastic wastes as replacement of sand.**

Keywords: Waste PET, Light Weight Concrete, Polyethylene Terephthalate, Sustainability.

I. Introduction

Human have created and used a lot of plastic in last 100 years. It's affordable, durable, light and adaptable, but end up on the ground, burned in open air or pollutes the ocean at some point. Plastic remains in the atmosphere for a long time, endangering biodiversity and releasing toxins as well as contributes to global warming. Our dependency on plastic prolongs our need for polluting fuels. As almost all plastics is manufactured from chemicals derived greenhouse emitting fuels. Any piece of plastic ever produced and shipped to landfill or drop in the environment still exist, as per EPA (Environmental Protection Agency) [2]. According to recent estimates, the global production of plastic waste is increasing with 260 million tons of plastic manufactured per year. Between 1950 and 2017, only 9% of globally produced plastic (6.4 billion metric tons) was recycled while 79% was disposed of in landfills and 12% was incinerated [3]. Plastic rubble kills approximately 100,000 marine animals annually in addition as score of birds and fishes [4]. Plastic landfill is also hazardous due to its sluggish degradation rate and bulky appearance. Plastic waste obstructs the movement of ground water. It also contains variety of toxic elements such as cadmium and lead, which can combine with rainwater and pollute ground water table and soil strata.

How is India attempting to address the plastic waste problem?

According to the Indian Central Pollution Control Board (CPCB), nearly 15,000 tons of plastic of plastic was dumped in India every year [5]. As the problem of plastic waste is growing day by day, scientist, academics and entrepreneurs all over the world have started to develop ways to help minimize it. Some are working on plastic disposal processes, whilst others are creating materials that are both sustainable and biodegradable. According to a study conducted by the National Chemical Laboratory (NCL) in India, 60-70 percent of PET bottles are recycled into different product, in particular polyester fibers that may be used as textile [6]. Various long lasting products are made with PET recycled bottle such as clothing, sofa cover, pillow stuffing etc. Another better solution is to use plastic in road pavement. Maharashtra has recently announced some of the project with this solution and some of the major cities had already applied it [7].

II. Plastic Waste as a Construction Material

The use of industrial by-products instead of cement is an appealing production process for safe, sustainable and eco-friendly construction material. The use of plastic waste into beneficial material (in concrete or mortar) has both, ecological and environmental advantages [8]. It decreases the negative effect on environment caused by production of cement, also decreases the consumption of non-renewable resources and the emission of greenhouse gases. It also benefit economically as cost of using plastic waste as substitute material in concrete reduce the production cost as well as reduce load on landfill.

Use of plastic waste as a substitution of aggregate is also a great solution. The global demand for building aggregate is expected to increase by 5.2% a year to 51.7 billion tons in 2019 [9]. Sand is exploited in large quantities for land reclamation efforts, natural gas exploration, and coastal replenishment systems. The excessive sand extraction from sea, river bed causes erosion. With concrete industry struggling to satisfy the demand for natural aggregates due to sluggish growth of sand, rising carbon taxes etc. use of artificial aggregates such as plastic, asphalt, fly ash and crumb rubber is gaining popularity. Every year, replacing 10% of aggregate by volume with recycled plastic has capacity to save 820 million tons of sand [10]. Plastic waste can also be used as fibers and filler. Table 1 shows common type of plastic used.

III. Effect of Plastic on Properties

A. Fresh Properties of Concrete

Utilization of HIPS as sand substitute shows that the workability of mortar does not changes dramatically when the HIPS replacement of sand is less than 20%. But the HIPS replacement is 50%, the flow ability became poor. The influence may be due to the shape of HIPS granules, which is not circular as sand [11].The reduction in workability was reported with increase in percentage of polystyrene [14]. Authors investigated the influence of plastic waste (80% PP +20% PS) on the workability of concrete. They found that with increase in 10%, 15% and 20% of plastic waste reduce the slump value up to 68.3%, 88.33% and 95.33% respectively. Due to non-uniformity in shape of plastic waste, fluidity get effected [15]. Waste PET light weight aggregate (WPLA) is replaced by the fine aggregate shows that flow value of mortar increase with increase in WPLA content. This is due to the fact that WPLA have circular shape and smooth surface which leads to easy flow and decreases the friction [16].

B. Bulk Density

Inclusion of HIPS as replacement of sand decreases the bulk density of mortar. Light weight mortar can be prepared with 50% HIPS [11]. Authors substitute sand with granulated PET of different size of aggregate (5mm, 2mm and 1mm) at the rate of 2% to 100% of volume of sand. The decrease in the bulk density is very low when the volume of PET varies between 2% to 50% but when volume increase by 50%, it drop rapidly until they reaches 1000kg/m^3. Bulk density decreases more with 5mm particle size of PET with same volumetric percentages [12]. Concrete composite having 50% of PET and PC plastic aggregate show the dry density of 1755kg/m^3 and 1643kg/m^3 respectively whereas conventional concrete have dry density of 2173 kg/m^3 [13]. Authors concluded that density got lower with increase in waste polystyrene (WP) content. 11%, 17% and 30% reduction in density is seen with inclusion of 20%, 40% and 60% of WP [14]. Incorporation of plastic waste as partial sand replacement 20% shows lowest density i.e. 2223.7kg/m^3 [15]. The unit weight of mortar having only PET aggregate were 1679 and 1694 kg/m^3. However, mortar with PET and sand aggregate both have dry density 1942 and 1937 kg/m^3 [17].

C. Compression Strength

Replacement of sand by PET up to 50% of shows 15.7% reduction of compressive strength in comparison to reference mortar. When the volume of sand is substituted by PET above 50%, the compressive strength drops rapidly [12]. Researcher investigated the effect of replacement of sand by HIPS on mortar by the volume of 10%, 20% and 50%. The reduction of 12%, 22% and 49% were found respectively for 10%, 20% and 50% HIPS proportion at 28 days of curing. Smoother surface of HIPS leads to worse interface between cement and aggregate, resulting in declination of compressive strength [11]. Similar results were also reported where incorporating PET and PC aggregate decreases the compressive strength. With 50% of PET and PC aggregate, 69% and 63.9% decline in strength is seen respectively [13]. On addition of WP in 20%-60%, with 20% successive addition show declined compressive strength with increasing WP content [14]. Plastic, being a hydrophobic material prevent water required for hydration of cement to enter the concrete during the curing process. This results in decrease of compressive strength with increase in percentage of waste [15]. 6%, 16% and 30% reduction in compression strength is seen with 25%, 50% and 75% of WPLA when compared to conventional concrete [16]. The compressive strengths of mixtures containing sand and PET is greater than those of mixtures containing only PET [17].

Table 1: Common Types of Plastic.

Type	Polyethylene terephthalate (PET)	High density polyethylene (HDPE)	Polyvinyl chloride (PVC)	Polypropylene (PP)	Polycarbonate (PC)	Polystyrene (PS)	High impact polystyrene (HIPS)
Uses	Food containers, oven ready tray, soft drink bottle	Toiletry bottle, garbage bag, juice container, milk bottle	Mineral water, plumping pipe, curtains, toys	Margarine tubs, disposal cups, straws, ketchup bottle, syrup bottle	Baby Sippy cup, mobiles, computer, discs, metal food can liner	Fish tray, egg carton, DVD case, plastic cutlery.	Electronic device, gasoline tank, recording tape

ISBN: 978-93-91355-11-1

D. Durability

With increase in rate of substitution, hydrous transitions in samples became slower due to the non-sorptive nature of PET. Shrinkage study reveals that when sand volume is replaced with PET increase from 0% to 30%, the PET aggregate have little effect on shrinkage as compared to the reference mortar. Modulus of elasticity of composite concrete decreases with increase in the percentage of PET as sand has higher modulus value than PET [12]. Sorptivity coefficient decreases 31% with respect to traditional concrete, when 25% of WPLA was used. Whereas, increases 15% and 52% with the used of 50% and 75% of WPLA. It can be inferred that inside porosity of mortar improves due to equalization of size of aggregate [16]. Lowering of modulus of elasticity is found as percentage of HIPS increases [11]. Replacement of sand by PET and PC by 3% and 10% does not have any significant change on water absorption but for 20% and 30%, water absorption increases. Linear drop was seen in elastic modulus with increase in percentage of PC and PET. The value drops from 37.3 GPa (0% PC and PET) to 14.2 GPa and 11.8 GPa for 50% of PC and PET aggregate [13]. The water absorption of concrete increases as the WP content increases. The value at 28 days ranges from 4.65% to 5.27% [14].

E. Tensile Strength and Flexural Strength

The declination in splitting tensile strength is seen with the increase in proportion of HIPS due to smooth and flexible surface of HIPS [11]. The sand substituted with PET and PC aggregate with percentage up to 10%, no significant change is seen in the flexural strength. However, with 50% of PET and PC aggregates, declination of 17.9% and 32.8% is measured respectively [13]. The flexural strength of waste plastic concrete mixtures at each curing age tends to decline as the waste plastic ratio increases. Lowest flexural strength was observed with 20% plastic waste at 28 days of curing i.e. 30.5% less than conventional concrete. This phenomenon was explained as the adhesive strength of concrete decrease between cement, plastic waste [15]. The flexural strength of mortar having PET aggregate only was comparable with mortar having sand and PET aggregate both until 180 days [17].

F. Thermal conductivity

Substitution of sand with HIPS by volumetric ratio of 10%, 20% and 50% decreases the thermal conductivity of mortar with 87%, 69% and 44% respectively. This depletion is due to poor thermal conductivity of HIPS in comparison to sand [11].

VII. Conclusion

Lots of research has been conducted on the use of different types of plastic waste as replacement of sand. Following findings of this study are:

1. Incorporating plastic waste in concrete/mortar considerably decrease workability. As workability depends upon various factors such as particle size and shape of particle. Uniform and round particles promote fast flow and reduce surface friction.
2. Regardless of type of plastic and percentage of replacement, use of plastic waste lower the density and weight of cement based material. So, recycled plastic waste replacement of sand is effective to produce a light weight concrete.
3. Compressive strength and flexural strength both reduces with increasing plastic waste content when replaced with sand. This is due to the fact that plastic surface has smoother and soft surface as compare to sand resulting in poor interface and adhesive strength between cement, sand and plastic aggregate.
4. Hydration of concrete slowdowns due to water repellent behavior of plastic waste which resist the entry of water into concrete. This further result in declination of strength property of concrete.
5. Elastic modulus of plastic waste is less than the sand lowering the modulus of elasticity of concrete having plastic waste. This reduction of modulus of elasticity is suitable for construction of pavement. Water absorption increases with higher substitution of plastic waste, due to weak bond between cement matrix and plastic waste aggregates.
6. Inclusion of plastic waste into concrete/mortar would be beneficial to the community and appear to be an appealing option as a low cost method of producing more versatile construction material which is light weight, compact, moisture resistant and durable.
7. Inclusion of plastic waste named as WPLA manufactured from PET bottles would be beneficial to the control the sorptivity that is the internal porosity in concrete or mortar up to 25 percent content by weight incorporation but beyond this the sorptivity coefficient increases.

References

[01] Degradable polymers, recycling and plastics waste management by Ann-Christine Albertsson, Royal Institute of Technology, Stockholm, Sweden and Samuel J. Huang, University of Connecticut, Storrs, Connecticut, Marcel Dekker, Inc, ISBN: 0-8247-9668-3.

[02] National Overview: Facts and Figures on Materials, Wastes and Recycling, United States Environmental Protection Agency. Available: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials

[03] Dufour, G.F., 2018. A Whopping 91% of Plastic Isn't Recycled. [online] News.nationalgeographic.com. Available at: https://news.nationalgeographic.com/2017/07/plastic-produced-recycling-waste-ocean-trash-debris-environment/ [Accessed 23 May 2018].

[04] Guern C.L., 2018. Plastic Pollution. [online] Available at: http://plastic pollution.org [Accessed 5 Jun. 2018].

[05] Anon, 60 cities generate over 15,000 tonnes of plastic waste per day [online]. http://timesofindia.indiatimes.com/home/environment/pollution/60-citiesgenerate-over-15000-tonnes-of-plastic-waste-per-day/articleshow/47110633.cms.

[06] Pulakkat, H. (2018). How India is trying to solve its plastics waste problem. [online] The Economic Times. Available at: https://economictimes.indiatimes.com/news/politics-and-nation/how-india-is-trying-to-solve-its-plastics-waste-problem/articleshow/64431263.cms [Accessed 29 Jun. 2018].

[07] News18. (2018). India Produces over 25,000 Tonnes of Plastic Waste a Day: Environment Ministry. [online] Available at: https://www.news18.com/news/india/india-produces-over-25000-tonnes-of-plastic-waste-a-day-environment-ministry-1618383.html [Accessed 1 Jul. 2018]

[08] Saikia N., Brito, J.D.: Use of plastic waste as aggregate in cement mortar and concrete preparation: A review. Construction and Building Materials. 34, 385-401 (2012)

[09] The Freedonia Group: World Construction Aggregates to Reach 51.7 Billion Metric Tons. [online] Prnewswire.com. Available at: https://www.prnewswire.com/news-releases/the-freedonia-group-world-construction-aggregates-to-reach-517-billion-metric-tons-300241261.html [Accessed 9 May 2018].

[10] Thorneycroft, J., Orr, J., Savoikar, P., Ball, R.J.: Performance of structural concrete with recycled plastic waste as a partial replacement for sand. Construction and Building Materials.161, 63-69 (2018)

[11] Wang R., Meyer, C.: Performance of cement mortar made with recycled high impact polystyrene. Cement and Concrete Composites. 34, 975-981 (2012)

[12] Marzouk, O.Y., Dheilly, R.M., Queneudec, M.: Valorisation of post-consumer waste plastic in cementitious concrete composites. Waste Management. 27, 310-318 (2007)

[13] Hannawi, K., Bernard, S.K., Prince, W.: Physical and mechanical properties of mortars containing PET and PC waste aggregates, Waste Management 30, 2312–2320 (2010)

[14] Herki, B.A., Safary, Z., Khalid, O.: Engineering Properties of Sustainable Lightweight Concrete Using Waste Polystyrene. International Journal of Engineering and Innovative Technology (IJEIT), 5(12), 23-27 (2016)

[15] Ismail, Z.Z., Hashmi, E.A.: Use of waste plastic in concrete mixture as aggregate replacement. Waste Management 28, 2041–2047 (2008)

[16] Choi, Y.W., Moon, D.J., Kim, Y.J.: Mohamed lachemi, Characteristics of mortar and concrete containing fine aggregate manufactured from recycled waste polyethylene terephthalate bottles. Construction and Building Materials 23, 2829–2835 (2009)

[17] Akcaozoglu, S., Atis, C.D., Akcaozoglu, K.: An investigation on the use of shredded waste PET bottles as aggregate in lightweight concrete, Waste management, 30. 285-290 (2010)

[18] Hebei-times.com. 2018. POM Plastic Raw Material Polyoxymethylene (POM FM090). [online] Available at: http://www.hebei-times.com/e_products_show/?id=13 [Accessed 10 May 2018].

 ISBN: 978-93-91355-11-1