Impact Of PET Plastic Waste On Mechanical Properties Of Mix Concrete Design

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Abstract: Plastic waste are the most dangerous material produced that can be harmful to humans and animals as well. Apart from this, it also affects the environment in number of ways. To reduce these adverse effects of plastic, this research deals with the preparation of concrete mixture from the PET plastic and cups along with the cement. This will help to reduce the plastic wastage present on the earth and also help to prepare strong concrete mixtures. In this research, the concrete mixture is prepared with cement, aggregates, water and some ratio of PET plastic. The plastic bottles and cups has been shredded by a plastic shredder to get the plastic coarse aggregate type of material. The ratios considered are 0.0%, 0.5%, 1.0%, 1.5%, and 2.0% of the actual cement amount. The cubes are prepared of mixtures for compressive strength test and beams are casted for preforming the flexural test. The tests of these results are presented in this thesis in an effective way so that it can be helpful in making other further decision or conclusion. Overall, the results indicate that the compression strength and flexural strength values decreased as the amount of PET plastic is increased in the concrete mixtures. There can be only some amount of PET plastic in concrete mixtures but it can't use high ratio of plastic in the mixtures.

Index Terms: PET material, Waste plastic, Slump test, Compressive test, Flexural test.

1 INTRODUCTION

People in today's world are consuming an enormous amount of raw materials. Because of this, natural resources are being quickly depleted. With the growth in the population, comes an increase of waste generated by the increasing demand for new highways, commercial buildings, housing developments, and infrastructure projects, which results in a tremendous amount of waste ending up in landfills yearly. With consumer and economic growth there will always be natural resources not only depleting eventually disappear. Research shows that there are many innovative uses of recycling and reusing waste materials in the construction industry. Currently, there is no document, which a researcher could find, that presents a collection of these materials, ready for use by contractors. Another problem is a lack of understanding of what constitutes as recyclable materials, and knowing their usages / alternative usages. To substantiate the researcher's claim provided are some applicable examples in regards to the construction industry (i.e., usages, sustainable materials, and pressing issues on reducing waste). According to UN estimates, every year the world uses 500 billion plastic bags while half of the plastic used is of single use or in disposable items such as grocery bags, cutlery and straws. Each year, at least eight million tonnes of plastic end up in the oceans, the equivalent of a full garbage truck every minute. In India, 70 percent of total plastic consumption is discarded as waste. Around 5.6 million tonnes per annum (TPA) of plastic waste is generated in country, which is about 15,342 tonnes per day (TPD). In the United States, over 7 billion pounds of polymerizing vinyl chloride (PVC) are thrown away yearly. Usages for flexible forms of PVC waste are hosepipes, insulation, and shoes. A use for rigid PVC waste is molded articles. Only 18 million pounds of that, about one quarter of 1% is recycled. Americans use approximately one billion plastic shopping bags, creating 300 thousand tons of landfill waste yearly. It should be noted that plastic is not biodegrade. Sunlight breaks plastic down into smaller and smaller particles that pollute the soil and water, which are costly and difficult to remove. In the landfills, plastic is shielded from sunlight delaying decomposing for thousands of years. Several alternatives in many different applications can be used today utilizing waste and recycled materials, and have proved to be little or no cost while reducing extracting raw materials, often cutting transportation costs, and can be positively used in the construction industry to capitalize on. Such plastic can be used in construction works in which pavements, roads can be built by mixing it with asphalt or concrete etc.

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Fly ash

Studies have shown that fly ash, a coal combustion by product of, poses human and ecological risks by containing significant quantities of heavy metals such as arsenic, lead, and selenium that can lead to the development of cancer and neurological problems [2]. Studies also have shown that fly ash, because of its uranium and thorium content is more radioactive than nuclear waste. However, several researchers have found fly ash is potentially good for use in the construction industry, instead of being stockpiled at off sites or filling landfills. Figure 1 shows dumping of piles of fly ash at an offsite in Virginia. Utilizations of fly ash in construction include, concrete production, structural fills, embankments, filter in asphalt mixes, and grouting.

Tire waste

An estimated number of one two billion scrap tires have been disposed of in huge piles across the United States. An additional 250 million tires unaccounted for are discarded yearly (Rubber Manufacturers Association, 2011).

Figure 1: *Fly ash being dumped (Rob Perks, 2009).*

Glass

Glass is another waste product filling landfills. In 2010, the United States sent 11.5 million tons of glass to landfills. The glass process consists of the super cooling of a melted liquid consisting of sand and soda ash. Glass is harmful to our environment because is not biodegradable, it takes millions of years to decompose into the raw materials it was made from.

E-waste (plastic, glass etc.)

E-waste refers to electronic equipment and products consisting of discarded personal computers, monitors, hard drives, copiers, facsimile machines, cellular phones, and televisions. The composition of e-waste consists of valuable recyclables but also include potentially hazardous material [4] [6]. Understanding that unscientific disposal of multi-layered plastics (MLPs) that are used to make pack ready-to-eat items like chips, biscuits etc, is a threat to the environment, Punjab is now working on a mechanism to effectively collect MLPs and then use it for road construction [11]. According to a study done on rag pickers by the Punjab Pollution Control Board (PPCB), it has been observed that there are around 28 different types of multi-layered plastic items which the rag pickers don't pick due to low returns, and so it is found littered on the streets, municipal solid dumps, and sometimes ends up clogging the drains. To ensure the collection of such plastic items, PPCB used the Extended Producer Responsibility (EPR) – a policy approach under which producers are given a significant financial responsibility for the treatment or disposal of multi-layered plastics. For research purpose, a small experimental stretch was constructed on a road passing through Ikolaha village in Ludhiana with the use of multi-layered plastics in June. The road stretch, which was constructed as part of the Pradhan Mantri Gram Sadak Yojana, was also tested by the Civil Engineering Department of Thapar University, Patiala which reported it to be up to the mark [12]. According to officials of Punjab's Public Works Department, further pilot stretches of roads (around 500 km) would be made with similar premix to work out the aggregate impact of multi-layered plastics in terms of strength and durability of roads.

2 LITERATURE REVIEW

Nabajyoti Saikia et al (2012) [9] studied that plastic waste can be used as a partial replacement of natural aggregate. From the results obtained from these studies it is concluded that: Two parallel views exist on the workability performance of concrete containing plastic aggregate. This is mainly due to the size and shape of plastic aggregate. The incorporation of plastic aggregate can reduce the density of resulting concrete and cement mortar and therefore several studies were undertaken to prepare lightweight concrete by using various types of plastic aggregates. H. Janfeshan Araghi et al (2015) [2] investigate that the effect of sulfuric acid attack on concrete resistance included various PET percentages (0, 5, 10, 15) as substitute aggregate by crushing load, weight change and ultrasonic wave velocity tests. According to results, it could be concluded that concretes included PET particles are able to utilize in environments under sulfuric acid attack. Raju Sharma et al (2016) [10] concluded that the direct inclusion of plastic in concrete does not effectively improve the strength of concrete. However, it is useful to treat plastic surfaces with reactive materials, such as iron slag, silica fume, and metakaolin. Thus, extensive research of durability parameters is required because little literature is available regarding these parameters. Thirdly, mixing fibers in concrete is one major problem in the production of fiber reinforced concrete. The properties of concrete vary as the plastic fiber content in concrete varies. Anurag V. Tiwari et al (2017) [12] studied the plastic Waste Bituminous Concrete Using Dry Process of Mixing for Road Construction and concluded that addition of plastic improves the Marshall properties of the mix. The Addition of 8% of the LDPE and HDPE plastic waste improves the stability value of the bituminous mix which results is the increase in the toughness of the mix. Abhishek Jain (2018) [3] studied that the workability and density of concrete specimens containing WPB decreased with increase in the percentage of WPB. The smooth surface and low density of WPB cause segregation and improper cohesiveness leading to declining in workability and density of concrete. However, workability can be enhanced by using suitable superplasticizer. From the previous researches, it has been found that to improve the performance of concrete mixes used in the surfacing course of modern road pavements. The choice of modifier for a particular project can depend on many factors including construction ability, availability, cost, and expected performance. The use of recycled plastics composed predominantly of polypropylene and low density polyethylene in concrete mixtures can assist with increased workability and high strength. The thrust of this study is to use crushed and cut PET bottles and cups and to add them in concrete mix with respect to ratio of cements.

3 MATERIALS USED IN RESEARCH

Cement

For this research work, Ordinary Portland cement of Grade 53 is used. The used cement was gray and free from lumps.

Aggregates

Aggregates are the materials which are used as the binding material in concrete in some fixed amount or proportion which help to produce the concrete. Because it helps concrete to gain it hardness, strength and durability to the created pillars, beams, slabs etc.

WATER

It is the main material for making the concrete as it participates actively in the chemical reaction of producing concrete. The water that needs to be used for making concrete must be free from impurities like alkalis, oil, acids etc. and cleanWater-Cementitious (w/c) Ratio contains the supply of water within the concrete, effect of water/cement-ratio on workability of concrete, hydration technique and in short overview of the effect of w/c ratio at the porosity and gel pores. Furthermore, concrete with the decrease w/c ratio has low capillary voids and the effect of water/cement ratio on the strength of the concrete.

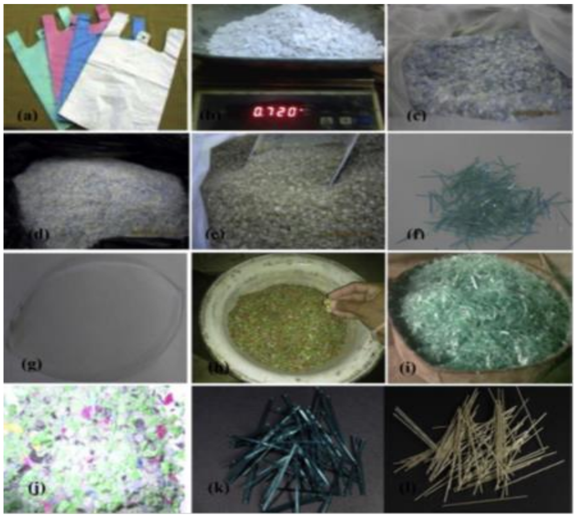

Figure 2: *Different forms of waste plastic: (a) Polyethylene (b) Sample of waste plastic (c) PET-aggregates PC (d) PETaggregate PF (e) PET aggregate PP (f) Short laminar fiber (g) Sample of 'O' fiber (h) Shredded fiber (i) Hand Cut fiber (j) Granulated Plastic (k) polyethylene terephthalate and (l) polyethylene terephthalate [10]*

Polyethylene terephthalate (PET)

Polyethylene terephthalate (PET) may exist both as an amorphous (transparent) and as a semi-crystalline polymer. It is an excellent water and moisture barrier material, plastic bottles made from PET are widely used for soft drinks PET in its natural state is a colorless, semi-crystalline resin. Based on how it is processed, PET can be semi-rigid to rigid, and it is very lightweight. It makes a good gas and fair moisture barrier, as well as a good barrier to alcohol (requires additional "barrier" treatment) and solvents. It is strong and impact-resistant. PET becomes white when exposed to chloroform and also certain other chemicals such as toluene. PET cups have been collected from municipal and landfills as a waste of human activities. These cups were cut into small size by using special cutting machine to become flakes. The resulted PET flakes are ready for mixing with Portland cement, sand and water.

Figure 3: *Collection of Polyethylene terephthalate (PET) bottles in actual and crushed form*

Figure 4: *Polyethylene terephthalate (PET) waste cup before cutting and after cutting*

4 RESULTS AND DISCUSSIONS

This section provides the aggregate tests that have been carried out by preparation, casting and curing of different types of concrete mixes. Compressive strength, flexural strength and slump tests has been carried after 7days, 14 days and 28 days of casting of specimens by taking four different proportions of crushed PET material in Original Mix design in which 0.5 %, 1%, 1.5% and 2% of crushed PET waste has been used with respect to cement used in original mix.

Mix design proportions and test results

Mix design is a way to select advisable values of different ingredients of concrete. For example 1: 1.65:2.41 has one ratio of cement. 1.65 ratios of fine aggregates and 2.41 ratio of coarse aggregate. Five samples are considered in this work in which crushed PET waste ratios are varied starting from 0% to 2% with .5% difference and M1, M2 M3,M4 and M5 names are given for all types of mixes. Table below shows the quantity of PET crushed bottles and cups w.r.t cement in the concrete mixture.

Table 1: *Name of concrete mix and proportion of PET waste in it*

Percentage of PET waste plastic	0.0%	0.5%	1.0%	1.5%	2.0%
Name of concrete mix	M1	M2	M3	M4	M5

Compressive Strength Tests

The results of the compressive strength tests for the waste plastic concrete mixtures are shown in table 2.

Table 2: *Compressive strength test of concrete by varying %age waste PET material*

Mix design	Sample No.	Compressive strength test (kN/mm2)		
		7 Days	14 days	28 days
M1	S1	28.99	35.19	39.22
	S2	28.78	35.25	39.31
	S3	28.77	35.42	38.80
M2	S1	25.74	31.81	36.11
	S2	25.31	30.97	35.63
	S3	25.88	31.87	36.35
M3	S1	25.85	31.86	36.09
	S2	25.26	30.95	35.73
	S3	25.85	31.80	36.27
M4	S1	23.25	30.54	34.58
	S2	23.69	29.10	33.67
	S3	23.61	29.80	34.27
M5	S1	22.53	28.91	33.19
	S2	22.71	27.89	32.75
	S3	22.77	28.72	33.49

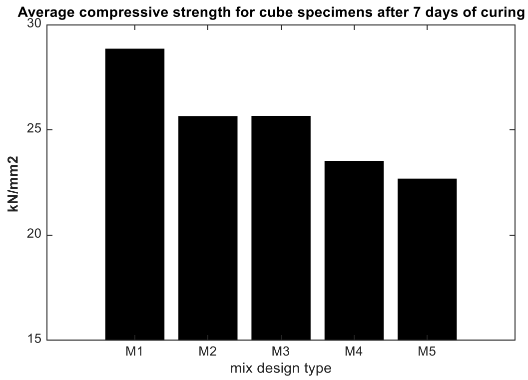

Figure 5: *Comparison of average compressive strength for concrete mix after 7 days*

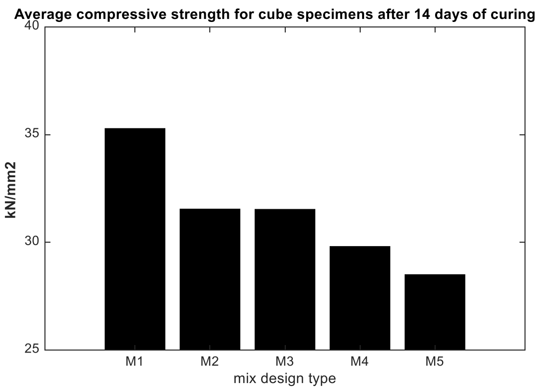

Figure 6: *Comparison of average compressive strength for concrete mix after 14 days*

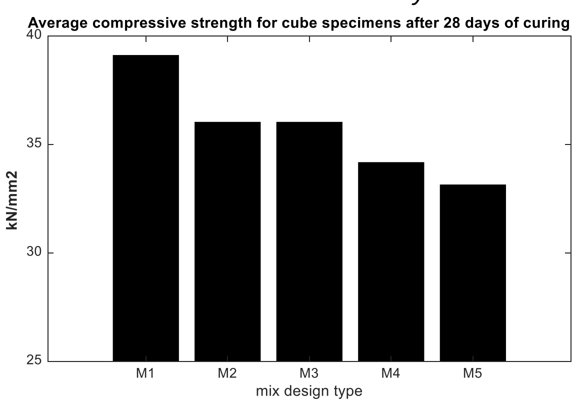

Figure 7: *Comparison of average compressive strength for concrete mix after 28 days*

Above figures shows the result of average values of compressive test for concrete mix after 7, 14, and 28 days. It can be seen that the compressive strength of the concrete mix is decreasing with the increasing ratio of PET material's amount. The highest compressive strength is found for the 0.0% ratio in which only cement was used. The constant compressive strength was found for mixtures M2 and M3. This shows that the increasing amount of PET waste led to the decrease of compressive strength of the concrete mixture.

Flexural Strength Test

The results of the flexural strength tests for the plastic concrete mixtures M1, M2, M3, M4 and M5 are illustrated in Table 3.

Table 3: *Flexural tensile strength test of concrete by varying %age of PET material*

Mix design	Sample No.	Flexural strength test (Mpa)		
		7 Days	14 days	28 days
M1	S1	1.97	2.05	2.68
	S2	1.91	2.08	2.72
	S3	1.95	2.03	2.64
M2	S1	1.86	1.96	2.54
	S2	1.88	1.99	2.50
	S3	1.86	1.96	2.54
M3	S1	1.79	1.87	2.49
	S2	1.76	1.92	2.38
	S3	1.77	1.82	2.34
M4	S1	1.71	1.81	2.29
	S2	1.70	1.77	2.30
	S3	1.60	1.78	2.36
M5	S1	1.71	1.81	2.26
	S2	1.63	1.82	2.37
	S3	1.60	1.75	2.26

Below figures 8 to 10 shows the result of average values of flexural test for concrete mix after 7, 14, and 28 days. It can be seen that the compressive strength of the concrete mix is decreasing with the increasing ratio of PET material. The highest flexural strength is found for the M1 in which the PET material is not used in the complete mixture. The increasing amount of PET material results in the continuous decrease in the Flexural ratio.

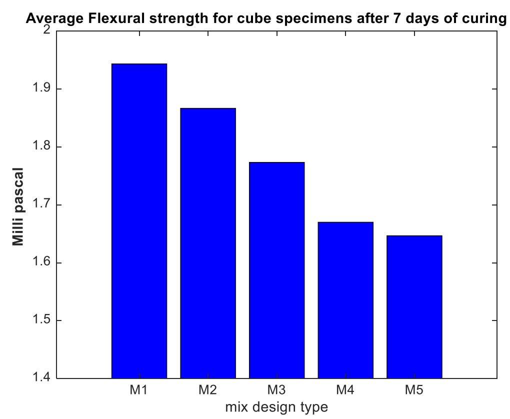

Figure 8: *Comparison of average flexural tensile strength for concrete mix after 7 days*

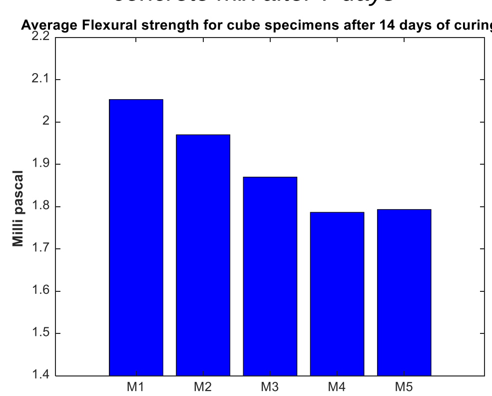

Figure 9: *Comparison of average flexural tensile strength for concrete mix after 14 days*

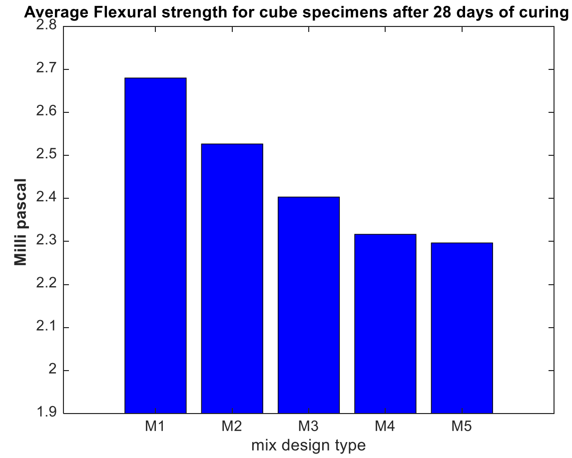

Figure 10: *Comparison of average flexural tensile strength for concrete mix after 28 days*

Slump test

The value of slump test has been carried out for 5 samples of mixtures prepared for the different amount of PET material and cement.

Table 4: *Slump test for 5 different types of concrete mix design*

Mix design	Proportion of PET waste material	Slump (mm)
M1	0 %	69.6
M2	0.5%	61.5
M3	1%	57.7
M4	1.5%	53.0
M5	2.0%	51.2

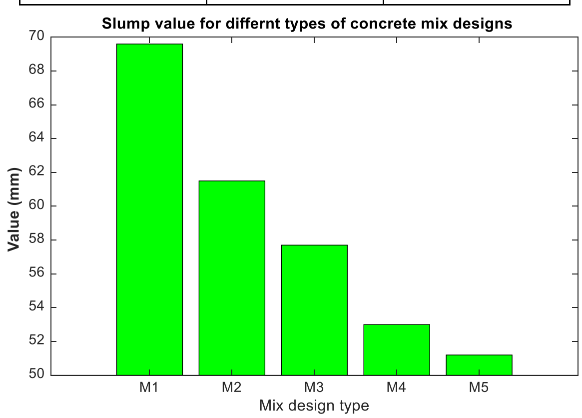

Figure 11: *Slump test for 8 different types of concrete mix design*

From Slump test results, it can be observed that the slump of Mix M5 is less as compared to the other four mixes. This shows that the thickness of the M5 is higher. This is due to the highest amount of PET materials in the M5 mixture. Because plastic material led the thickness of cement in M5 due to which the value of slump is low in this.

CONCLUSION

Plastic recycling is still a relatively new and developing field of recycling. Applications for recycled plastics are growing every day. Plastics can be blended with virgin plastic to reduce cost without sacrificing properties. Recycled plastics are used to make polymeric timbers for use in picnic tables, fences, outdoor toys, etc., thus saving natural resources. The problem of plastics wastes has increased tremendously since the use of plastics increased in most industrial, commercial, and residential applications. This research deals with using the plastic material to prepare the concrete mixtures that can be used to create beams, slabs etc. The mixtures were prepared in the ratio of 0.0%, 0.5%, 1.0%, 1.5%, and 2.0% of the complete mixture. For the compressive test, the casted cube's size is 75mm*75mm*75mm. Similarly, for the flexural test, the casted beam's size is 500 mm *100 mm * 100mm. After the testing, the results indicate that the compressive strength and flexural strength of the concrete mix is decreasing with the increasing ratio of PET material's amount. The highest compressive strength and flexural strength ratio is found for the 0.0% ratio in which only cement was used. This shows that the increasing amount of PET waste led to the decrease of compressive strength and flexural ratio of the concrete mixture.

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