Use of plastic waste as recycled material in the concrete

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Abstract. In this study, we examined the effect of adding recycled plastics to concrete. The waste plastics were collected from a local market. The disposal of plastics is a major issue with many negative consequences. Plastic, being inorganic, does not change the chemical characteristics of concrete and has no effect on its quality or consistency, making it an ideal material for use in the construction industry, where it may help reduce plastic waste. Plastic has dual uses in concrete as a filler ingredient and as an additive to enhance the mechanical properties of the material. The concrete was prepared using five different amounts of aggregate substitution by volume: 10%, 20%, 30%, 40%, and 50%. Cubes and beams were cast, cured, and tested using a universal testing machine. A mixed proportion was made using the different ingredients used in the concrete. At 7, 21, and 28 d, the results showed that the compressive and flexural strengths increased as the percentage of plastic waste increased. Also, flexural strength improved with an increase in the proportion of plastic waste, reaching a maximum at 30%. These results highlight that, as plastic fiber decreases the quantity of industrial fibers needed in concrete, it is also proven to be more inexpensive.

Keyword:- Plastic waste, recycled material, concrete, compressive strength, flexural strength, performance, properties.

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1 Introduction

Plastics play an important role in daily life. Plastics are used in almost all the manufacturing processes. Although they continue to produce waste, tons of plastic products are produced daily. Since most plastics are not biodegradable, the world continues to produce a large amount of plastic waste; developed countries are the biggest importers of plastic waste, especially plastic waste, which comes in the form of packaging and containers. Land disposal is a major global concern. Polyethylene containers including bottles and food boxes were used in this study. Up to 60% of plastic waste, both industrial and municipal, is recycled from various sources. People in India have eliminated several types of waste, including plastic waste, which has huge economic benefits because plastic recycling and disposal play an important role in the industry [1-3].

Since its invention in the early 20th century, plastic has grown into the most pervasive and adaptable substance; without it, modern existence is inconceivable. Solid waste management has been around for a long time because people always need a place to put their trash. Its low price, portability, and long lifespan make it a major challenge. Despite the versatility of plastics, businesses are increasingly struggling to find sustainable ways to dispose of their excessive packaging trash [4]. Plastic waste disposal is inevitable because of its abundance and limited biodegradability. Every year, the world's seas get a deluge of plastic trash—a "plastic soup"—that has a breakdown time of several million tons. Every year, marine creatures and birds lose their lives as a result of consuming microplastics [5]. Waste from households and landfills has been packed with soluble packets made of polyethylene packets that contain waste from households [6-7]. The three most common types of plastic trash are polystyrene, polyethylene terephthalate, and polypropylene. This exclusive perspective highlights the significance of garbage recycling [8]. This type of energy production allows us to store and conserve non-renewable botanical resources, reduce environmental pollution, and reuse and recycle energy. The problem of plastic waste threatens worldwide and is a global problem. Waste dumping sites create a lot of pollution or may affect health hazards.

It has several potential applications such as mineral infill cloth, a component of composite fabric, and a concrete combination [9]. One way to deal with the problems of plastic waste dumping is its use in concrete and road pavements. Several studies have shown that the utilization of plastic waste in concrete enhances its strength. To reduce the strain on the environment and reduce power usage, scientists have encouraged the use of plastic waste in concrete to enhance sustainability and environmental performance. Skilled engineers strive to minimize negative outcomes while maximizing positive outcomes for the economy, society, and environment. To be considered eco-performance, the focus is on improving a process's efficiency in reducing pollutants [10-12].

The advent of modern lifestyles, industrialization, and technological advancement has resulted in a remarkable increase in the amount and types of waste. Annual accumulation of waste is a global problem. Waste has emerged as a major environmental issue when disposed in landfills, quarries, rivers, and oceans. Recently, PETs have become the most harmful pollutants in the environment [13]. There are places where they can be found on top of the hills down in forests across watercourses around public recreational spaces, as well as at outskirts of residential areas. They also happen to be biggest polluters of European waters, with 14% representing all plastics thrown into rivers across Europe [14]. Among the priority objectives for environmental policies, we should mention the collection and recycling of this rubbish. Besides its non-combustible nature, it returns to nature through plastic packaging. However, what about abandoned uncollected and unused? Because it takes such a high proportion (about 12%) among other landfill volumes primarily made out of bottles of
polyethylene terephthalate (PET), incineration is increasingly attractive for recovering energy recovered from waste, but its influence on atmosphere by combustion gases is negative [15-16]. However, the utilization of plastic waste in construction is challenging. This study aims to contribute to environmental pollution by providing an environmentally friendly and renewable alternative concrete that incorporates recycled waste from the PET waste category as much as possible [17]. The aim of this study was to use waste storage, which currently has a low recycling rate. Consequently, PET waste may be initially treated using rolling and shearing technologies and then utilized as concrete reinforcement in subsequent steps. One such lightweight, non-corrosive, and recyclable material is terephthalate (PET) [18]. Synthetic fibers or fabrics can be made from these materials. Examples of plastic containers that fall under this category are juice, beer, wine, vegetable oil, and colorless or colored PET bottles [19].

2 Materials

2.1 Cement

Cement is a binder, a building material that provides strength and stability and holds other materials together. The cement in concrete acts as a binder and binds all ingredients. Many ingredients have been used in concrete, as demonstrated in previous studies [20-24]. The production of masonry mortar, concrete, and a combination of cement and aggregate for the manufacture of durable building materials are important types of cement that are used as raw materials. In accordance with IS: 12269-1987, ordinary Portland cement (OPC) of grade 53, which is available in the local market, was used in Fig. 1. The cement was tested in laboratory, and results confirmed a specific gravity of 3.14 with normal consistencies 30%, 50, and 320 min as initial and final setting times.

Fig. 1. Cement used

2.2 Fine Aggregate

Sand is the main component of concrete. Previous studies replaced sand with industrial waste. However, in our study, we replaced the coarse aggregates with plastic waste [25]. Fresh, local, and organic-free sand was used in this study. Fine aggregate (FA) was purchased locally prior to use in the experiment [26]. Its properties were examined in terms of bulk density, void ratio percentage, specific gravity, and fineness modulus [27]. The results observed as bulk density of 1.49 g/cm³, percentage of voids ratio as 34.23, specific gravity as 2.258 and fineness modulus as 2.9. Aster that sieve analysis was performed, and as per IS: 383-1970, the test confirms that it belongs to Zone II. To confirm IS 383–1987, locally available Natural River sand was used as the second filling area as shown in Fig. 2.
2.3 Coarse Aggregate

Coarse aggregate (CA) is another component used in concrete in Fig. 3. Materials with a particle size of more than 0.19 inches are considered coarse aggregates, which typically have thicknesses ranging from 3/8 to 1.5 inches [28]. Crushed stone and coarse rock are the two main types of coarse aggregate used in concrete. We employed crushed aggregates with sizes between 10 and 20 mm in this investigation. It weighs 2.85 metric tonnes. I.S. 383:1970 was used to assess the fine aggregate quality. The CA test confirmed a specific gravity of 2.74, bulk density of 1468 kg/m$^3$ and fineness modulus of 7.17.

2.4 Water

Concrete requires water as the ingredient. It plays a key role in the chemical processing of cement. It is crucial to keep a close eye on both the quantity and quality of water. For this study, we mixed the concrete and rinsed the sample using plain potable tap water from the lab [29-30]. You should usually utilize water that is safe for drinking. Thus, it is certain that the water is pure and devoid of any contaminants that might affect the concrete's set, hardness, strength, pit value in the trough, and other desirable qualities.

2.5 Plastic waste

Disposal of plastic waste is a major problem in cities because it has a negative effect on the environment. Low-density polyethylene (LDPE), in the form of plastic bags, is the most common waste generated by households. When dumped openly, plastic bottles cause...
environmental pollution and lower environmental sustainability. In most cases, they burn on the side of the road, producing smoke that causes air pollution. In this study, the plastic bottles were crushed and cut into small strips. Five replacement percentages, that is, 10 %, 20 %, 30 %, 40 %, and 50 % were considered as replacements for CA in the concrete as shown in Fig. 4.

![Plastic waste](image)

**Fig. 4. Plastic waste**

### 3 Experimental Plan

The experimental program was conducted on cubes and beams, with a focus on M60 grade concrete. Thirty cubes and 30 beams were cast, cured, and tested. As per Indian Codal Standards, the standard dimensions of the cubes and beams were cast. A universal testing machine was used to test cubes and beams. Concrete was created by hand on a waterproof platform. Prior to adding sand, the dry ingredients of cement, fly ash, and silica fume were thoroughly mixed. The steel fibers used to strengthen the concrete were evenly dispersed, while the mixture was manually mixed. The chemical admixture and water were carefully introduced throughout the mixing process. Manageable consistency was achieved by stirring the mixture. The concrete molds were filled at three levels. To improve the compaction, the concrete cubes in each layer were compacted 25 times. A table vibrator was used to vibrate the cube molds. The vibration lasted for one minute to ensure uniform compaction. Samples were demolded 24 h after pouring and placed in a curing tank for seven days & 28 days. Curing is the process of curing a concrete specimen or concrete structure under water at different frequencies. Dates of samples. As the paver block cures for 15 to 21 days, it is then tested for compressive strength in Fig. 5.
A UTM was employed to test the cubes and beams. Flexural and compressive strength tests were conducted on the beams and cubes. The performance of the concrete mix was evaluated using a set-testing procedure for each test. In the case of M60 grade concrete, cube specimens were cured and tested. The M60 grades were determined by conducting a compressive strength test (CST) in accordance with the requirements of IS 516-1959. CST was measured on days 7, 21, and 28. Following IS 516-1959, the flexural strength was measured on a UTM machine by measuring the flexural failure loads. Cast beam specimens of standard size were used for the flexural strength tests. The beam specimens were tested after a 28-day cure period. The load was gradually increased until the beam specimen cracked, and the failure load was recorded with a 24-Hour flexural strength evaluation.

4 Results

4.1 Compressive strength test results

The evolution of compressive strength over 7 days for the above mentioned types of mixtures was plotted as a graph as shown in Fig. 6. The highest cubic compressive strength of 30% plastic waste was found to be 24.56 N/mm2 than the conventional control sample at 7 days (Figure 6a). Cubic compressive strength was found to be 49.59 N/mm2 for 30% plastic waste which is higher than the control sample at 21 days (Figure 6b) Cubic compressive strength was found to be 62.56 N/mm2 for 30% plastic waste which is higher than control sample is formed in 28 days (Figure 6c) Plastic bottle fibers Concrete reduces industry consumption of fibers and plastic bottle fibers appear more economical as compressive strength increases with plastic waste increase the percentage is the highest 30 %.
Compressive strength at 7 days

Compressive strength at 21 days

Compressive strength at 28 days

Fig. 6. Variation of compressive strength with different days

This decrease in strength after 30% plastic is due to existence of low adhesion between cement paste and plastic waste (see fig. 6). The strength of plasticized concrete mixtures decreased with increasing plastic content, and the strength of the bond was low between the cement paste and plastic waste. Cement water took place near the plastic surface, which was reduced owing to the insolubility of plastic. This indicates that an increase in plastic waste enhances the strength of concrete up to a certain percentage, followed by further addition, with possibly a decrease in strength.

4.2 Flexural strength test results

The flexural strength development at 7 d for the above-mentioned types of mixtures was plotted as a graph, as shown in Fig 7. The cubic flexural strength was found to be 6.121 N/mm² for 30% plastic waste, which is higher than control sample at seven days. The cubic bending strength was found to be 6.434 N/mm² for 30% plastic waste higher than the control sample at 21 days. The cubic bending strength was found to be 5.888 N/mm² for 30% plastic waste higher than the control sample at 28 days. Plastic bottle fiber; the number of industrial fibers used decreased and plastic bottle fibers proved to be more economical as the strain rate increased, while the percentage of plastic waste 100 up there is a maximum of 30%.
This defect can be attributed to the lack of cohesion between concrete and plastic waste because it reduces the interfacial strength and weakens concrete. In addition, the lack of strength of plastic materials in density is the lack of cohesion between materials, plastic, and concrete waste, and after completing and reviewing the results, the flexural strength of concrete is reduced when plastic is present, as shown in Fig. 7. There is evidence that the tensile strength of concrete can be enhanced by incorporating plastic sealants into the concrete mix. Results showed that the tensile strength of concrete was higher than that of control concrete (i.e., concrete without fibers), and it was lower than that of concrete with mixed fibers up to approximately 30%.

**5 Conclusion**

Plastics play a significant role in our daily lives. Plastics are used in almost all manufacturing areas. Daily, tons, and tons of plastic stuff are shaped, while waste keeps building up. Because most plastics do not decay, there is an enormous build-up of materials worldwide; industrialized nations are major contributors to this. Specifically, packaging and containers account for the bulk of the plastic waste. The amount of land required for landfills is becoming an increasingly global problem all around the world. In addition, such research was conducted with the help of polyethylene bag wastes, including some bottles and crates meant for food amongst other debris from different sources. Thus, our study utilized plastic waste at various percentages ranging from 10% to 50% by volume in concrete mixtures. Tests were performed on cubes and prisms to determine their compressive strength and flexural...
strength, respectively. The following results were noted regarding the usage of plastic waste in concrete:

- The 30% plastic waste had a cube compressive strength of 24.56 N/mm², higher than the control specimen after seven days. The cube compressive strength was observed as 49.59 N/mm², which is higher than that of the control specimen for a period of 21 days, while it was noted to be 62.56 N/mm² which is greater than that of the control specimen for twenty-eight days.

- The flexural strength of the cubes was found to be higher at 7 days and as far as this is concerned, it can be concluded that this is caused by the increased percentage of waste plastics.

- For instance, flexural strength has been achieved using plastic bottles and fiber-reinforced polymers (FRP), which are used as reinforcing agents within concrete members.

- This can further result in a low water absorption rate, in addition to enhancing its durability; hence, unnecessary repairs are not required.

- The quantity of fibers used in industrial concrete should be reduced by means of plastic bottle fibers and also because of its economic advantage, since Flexural Strength increases with increasing percentage of plastic waste up to maximum value of 30%.

- From an economic perspective, we may justify our findings using a similar language like “in those lights”.

References


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