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Experimental Study on the Effect of Industrial Waste Plastic that Partially Replace with Cement and Fine Aggregates

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A B S T R A C T

In most of the country's cities, plastic waste has become a nuisance. Many cities have not effectively managed their plastic waste. Plastic waste is an environmentally favorable solution accessible for reducing environmental effects. This study examines the impact of using recycled plastic waste (RPW) as a partial replacement for cement and fine aggregate (F.A). Standard testing for cement, fine aggregate, and coarse aggregates was carried out. Experiments were carried out to replace fine aggregate with RPW at varied percentages (15%, 30%, 45%) and cement with varying percentages (10%, 15%, 20%). Concrete cubes sized 100 x100 x 100mm were cast. we studied and compared the properties of fresh and hardened concrete. The Compressive strength tests were performed for concrete curing ages of 7 and 28 days. The experiment demonstrated that replacing up to 30% of fine aggregate and 15% of cement with RPW resulted in improved concrete strength. Using waste plastic in concrete reduces the cost of Construction leads to environmental sustainability.

1. Introduction

For any nation to have economic prosperity, the building sector is crucial. Since the generation of Large waste has become one of the biggest major problems in the world; There are initiatives to recycle this garbage and use it in concrete. It was easy to get small aggregates from river water, and the demand for them increased. The environment has recently been affected by the construction of sand mining, and it has become difficult to meet the demands of building materials, so the cost of small aggregate has increased. The implementation of the constriction has been halted due to the unavailability of sand. since it significantly affects the price and rate of construction Cement is the primary component of concrete, and large amounts of it are required for building. In terms of mass, it is the second-most-used substance. following water. The energy required to produce cement is huge, and it releases a lot of CO2 emission [1].

As a result, it is costly and bad for the environment. Complete construction is necessary for projects using significant amounts of raw materials. The development of a country is reliant on its infrastructure. Old materials are replaced with new ones, resulting in an improvement in economy, strength, and quality. One of the most common uses is the construction of bituminous roads using plastic garbage. The use and existence of plastic bags and litter have gained attention recently. one of the best utilized in road building for recycled plastic. Now, the availability of trash and plastic consumption is high.. As the Plastic is an integral element of our daily lives. If it's not utilized again, Currently, distribution is done through backfilling or burning. Both have a negative impact on the environment [2]. Building environmentally friendly roads is a global priority for both developed and developing nations. It has increased in response to rising demand, in an effort to lessen the negative effects of road development, and in an effort to green our fundamental substructure. As a result, plastic debris was gathered and sorted from several trash dumps. Next, wastes made of high-density polyethylene (HDPE) were selected in order to conduct several testing. to different procedures [3].

It was difficult to manage waste and dispose of it is very difficult because of the rapid industrial and economic progress, so measures began to be taken to solve this complex problem. Scientists and researchers tended to invent good alternatives to natural aggregates and alternatives to cement. [4–8]. Recently, a lot of research has been done on substituting waste by-products from the manufacturing, automotive, and electrical sectors for natural aggregate. In 2018, the global production and use of plastic surpassed 359 million tons [9]. Polycarbonate and acrylonitrile butadiene styrene combine to form the thick plastic known as acrylonitrile butadiene styrene (ABS) [10].

The development of novel materials presents new challenges for policymakers in limiting their adverse effects. In recent years, the problem of disposing of plastic waste has become a very big and important problem to avoid the negative effects resulting from it on human health and the environment [11].

Many studies have been conducted on the use of plastic fibers in concrete from the 1990s to the present. Since then, studies have also examined the use of polymeric resins and recycled plastic aggregates [12].

Utilizing polymer waste as an additive in concrete can yield several advantages, such as reducing the material's weight and density, lowering its absorption rate, and improving its toughness, ductility, and impact resistance. In addition, the properties of polymer-reinforced concrete such as sound and thermal insulation improve, and the total durability of concrete and the compressive strength of the types of polymers used and the proportions of their placement and installation vary [13,14].

A specific type of plastic waste was chosen as an alternative to cement and fine aggregate in this research, and after a lot of research, it was found that the waste produced by humans is usually from 30% to 40% of inorganic materials and 60% to 70% of organic materials. By focusing on the non-organic portion, particularly plastics, this study aims to explore the potential of recycling these materials while assessing their effects on concrete performance. Plastic waste constitutes a significant portion of non-organic waste, with plastic packaging and bags being among the most prevalent types. Concrete mixtures that contain recycled and waste plastic have a highly beneficial effect on the environment since they solve the waste materials problem while also employing plastic for construction.

According to the analysis, adding 10% of plastic trash into the concrete mixture can aid in lowering the quantity of plastic waste that ends up in the environment [15]. It is both sustainable and economical to use waste plastic in construction projects in place of cement and aggregate. Using at least 35% of plastic waste in concrete has been shown to improve environmental and economic outcomes. [16].

Recycling plastic into construction materials offers a dual benefit by mitigating environmental impact and lowering disposal costs, as plastic can replace components like sand, gravel, or fiber in concrete mixes [17]. The use of plastic waste in concrete components reduces the cost of construction in addition to the proper and safe disposal of plastic waste. In addition to significantly reducing production costs according to this research [18], there is still little research into the use of waste plastic as a significant substitute in concrete.

The major aim of this research is to use waste plastic as a replacement for cement and fine aggregate. Utilizing this waste in construction projects will significantly save construction costs because it is an undesirable resource and a nuisance in the surrounding area. Different ratios of cement are replaced with plastic waste powder (90 ᴍ passing). The fine aggregate is substituted with variable amounts of obtained plastic waste, which passes through a 5 mm filter.

2. Materials and Methods

2.1. Materials

First of all, the resources needed for this study have been carefully acquired. After being separated from recycled plastic waste (RPW) with 200 mm size and passing through a 5 mm EPC sieve, the plastic waste materials were recovered. ٤٢,٥ grade Portland cement and ground natural sand were used as cement and fine aggregate, respectively, in this research, with a partial replacement of plastic waste with a sieve analysis of 170 sieves with 90 ᴍ ECP cement and a 5 mm sieve. The main aim is to obtain both cohesive and adhesive amounts. Table 1 shows the chemical properties of powder content. Coarse aggregate with a size of 20 mm sieve and small aggregate of a size of 5 mm sieve were used in concrete components. In this research, we used a type of recycled low-density polyethylene (LDPE) plastic waste, which is frequently used in soft drinks and foodstuffs. Table 2 Characteristics of cement and aggregate Figure 1 depicts the various raw components needed to manufacture the concrete mix. Figure 2 grading the grading of RPW.

Table 1 Chemical properties of low-density Polyethylene and cement

Parameter	LDP Value (%)	cement Value(%)
Na_2O	2.69	0.17
MgO	1.83	1.86
Al_2O_3	12.52	5.29
SiO_2	62.56	20.48
K_2O	1.30	0.41
CaO	12.01	65.02
TiO_2	0.62	-
MnO	0.12	-
Fe_2O_3	5.82	3.31
SO_3	-	2.73

Table 1 Chemical properties of low-density Polyethylene and cement

Properties	Values
Powder:	
Initial setting time	40 min
Final setting time	300 min
Cement specific gravity	3.15
Plastic powder specific gravity	2.7
Aggregates:	
Fine aggregates specific gravity	2.6
Coarse aggregate specific gravity	2.74
Mixture:	
Standard consistency test	28%

2.2. Methodology

The mixture ratio was calculated in accordance with Egyptian code 203. 2006. The mixture is designed in the following proportions1: 1.55: 3.07ratio ,400 Kg/m3 of cement, 1201 Kg/m3 of coarse aggregates, 606.54 Kg/m3 of fine aggregates and 70 mm of slump. W/C ratio: 0.5. The (100mm x 100mm x 100 mm) cube of concrete was cast in Laboratory of properties and resistance of materials at the Higher Future Institute of Engineering in Fayoum Using a brush, grease or oil is applied to the interior surfaces of molds. The molds are set up on a level surface. Four layers of concrete are poured into molds. Using a tamping rod and 25 strokes, each layer is flattened. To release trapped air in concrete, molds are subjected to a mechanical vibrator for three to five minutes. Using a trowel, level the top surface. Cast for 24 hours, the cubes were carefully removed from the mold. After that, the samples were placed in water.

To measure the compressive force, a pressure testing machine with a capacity of 2000 KN CTM was used, and cubic samples measuring 100 mm x 100 xmm100mm were used. To complete the test, the sample was placed between the loading surfaces of the testing machine and loaded until the fracture and then recorded the maximum load of the sample. Three test specimens were cast for each test condition, and the average values were taken into account to determine the compressive strength.

In this experiment, different percentages of powdered RPW waste were used in place of the fine aggregate. Additionally, RPW powder was used in place of cement. Table 3 presents the details. The cubes that were cast in these different ratios underwent. ntages of powdered RPW waste were used in place of the fine aggregate. Additionally, RPW powder was used in place of the cement. Table 3 presents the details. The cubes that were cast in these different ratios underwent curing and compressive strength tests after 7-days and 28- days. Figure 3 shows caste and test cube.

Table 3 Percent replacement of fine aggregates and cement with RPW

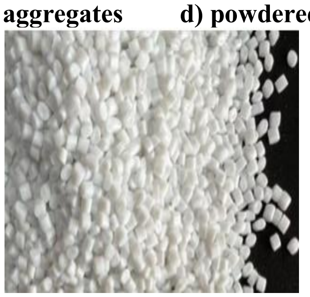
Component	F.A	Cement
RPW	15, 30, 45	0
Powdered RPW	0	10, 15, 20

a) Cement

b) Coarse aggregates

c) Natural fine aggregates

d) powdered plastic waste



e) plastic waste

Figure 1 Material used in mixing concrete

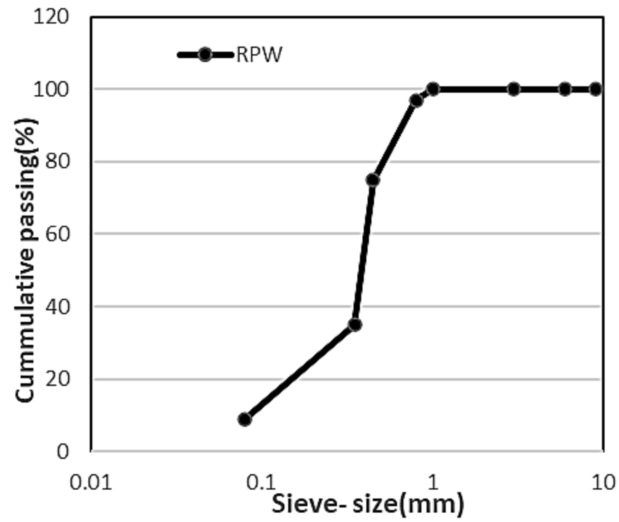


Figure 3 RPW Grading curve

a) Cube casting **b) Testing of cube**

Figure 3 Cubes Casting and testing

3. Result and discussion

The basic criterion for determining concrete strength is its compressive strength. Minimum compressive strength required for the concrete cube, as per the mix design, is 20 N/mm2. The findings of various concrete mixtures' compressive strengths are covered in this section.

3.1. Normal concrete

When comparing the control concrete mix with 30% recycle plastic fine aggregate substitution to other mixes, it is clear that the mix has the highest recorded compressive strength of 35 N/mm^2.

3.2. Using RPW in place of natural fine aggregate

There was a range of replacements for the natural fine. The 7day , 28ay strengths of regular mix concrete with natural fine and coarse material without replenishment are displayed in Table 4. After 28 days. Table 4 shows the seven and twenty-eight-day strengths of standard mix concrete with natural fine and coarse material without resupply with minimal compressive strength aggregate, ranging from 15% to 45%.

3.3. Using RPW in place of cement

Following research on the substitution of fine aggregate, RPW was used in various percentages—from 10% to 20%—to replace cement in the process. The concrete mix with RPW in place of cement is shown in Figure 5. The findings indicate that replacing 15% of the cement with recycled plastic waste results in a strength that is roughly equivalent to regular concrete. Gradually, as cement replacement rises, the strength increases and subsequently diminishes

Mix	Compressive strength (N/mm^2)	
	7 days	28 days
Normal concrete	22.4	22.4
Replacement of FA:		
15%	21	30
30%	24.7	35
45%	16.8	20
Replacement of cement:		
10%	23	32.8
15%	27	36
20%	25	34.9

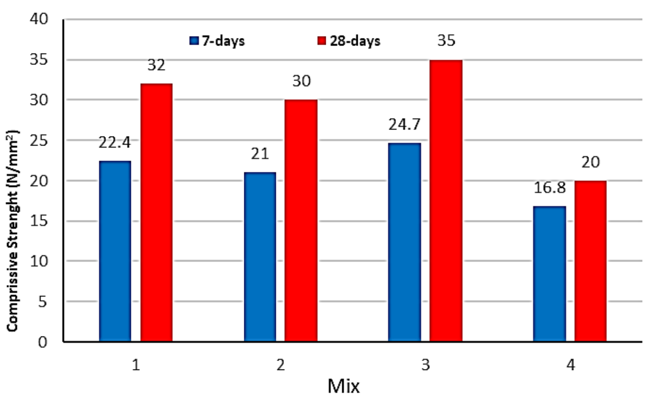


Figure 4 Compressive strength variation of different mixes containing RPW as fine aggregates

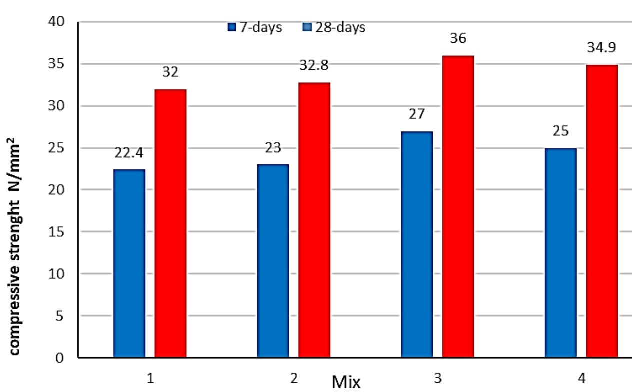


Figure 5 Compressive strength variation of different mixes containing RPW as cement

4. Conclusions

It is possible to use RPW as an alternate material in concrete, which increases its cost-effectiveness. Replaced concrete will significantly save construction costs when used in large-scale concrete projects. Waste products have replaced around 20% of the raw components in concrete. From every angle, it is observed that using plastic waste in concrete is quite successful. It is evident that the specimen yielding the maximum strength includes 30% of waste plastic as replacement of fine aggregate. based on the results of the experimental inquiry, adding up to 30% fine aggregate and 15% concrete's strength increased with the substitution of RPW cement. The reduction of calcium compounds explains the strength reduction associated with a higher percentage of cement replacement. In each of the above cases, the strength attained at this point is nearly identical to that of regular concrete. In every aspect, it has been discovered that using plastic waste in concrete reduces carbon footprint and prevents landfill-related environmental degradation. Additional research on the durability of mixtures and the chemical analysis of the constituents may support the current findings.

Conflict of Interest

The authors declare no conflict of interest.

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