Mechanical Behaviour of Concrete with Recycled Plastics

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ABSTRACT

The consumption of plastic has grown substantially all over the world as well as in Sri Lanka in recent years and this has created huge quantities of plastic-based waste. Although steps have been taken to reduce consumption of plastic, plastic waste has now become a serious environmental threat to the modern way of living. This creates a substantial amount of garbage every day which is a much unhealthy problem. In order to resolve this problem, recycled Polyethylene terephthalate (PET) flakes were proposed to be used as reinforcement material in concrete. This paper discusses the effect of adding PET flakes to the Ordinary Portland Cement (OPC) to manufacture sand mixed concrete. During this research work, the material properties, and the effect of PET flakes on the compressive strength of concrete were analyzed. Initially, the optimum PET flakes proportion was determined by testing 36 (150mm×150mm ×150mm) test cubes. The optimum plastic flakes percentage was found to be 3.0% and the PET flakes percentage was calculated based on the weight of the cement content of the concrete mix. Grade 20 concrete is proposed with 0.55 water-cement ratio with 3% PET flakes content.

Keywords*: Compressive strength, Manufactured sand, PET flake, Ordinary Portland cement.*

1. INTRODUCTION

The most widely used man-made material in the world is concrete. Buildings, bridges, dams, road pavements, sewage systems, tunnels, waste containment systems, and other structures are built using it. Compressive strength is one of its most significant and desirable properties. As a result, concrete is essential to be designed to develop its maximum compressive strength. (Akinwumi& Gbadamosi, 2014). The significant purpose of this study is to combine a waste material with cement to increase concrete's compressive strength.

Plastic is a worldwide substance that has become an integral component of our modern lifestyle, and as a result, global plastic manufacturing has increased in recent decades. PET is a polyethylene terephthalate (PET) that is often used in the packaging of a variety of items. PET containers are light, clear, and impact resistant, and they do not interact chemically with the contents. They are also non-toxic. All of these traits have helped them establish a strong influence in the polymer market and in the worldwide business. (Liliana Ávila Córdoba, et al., 2013).

The usage of excessive plastic has contributed tremendously to the enhancement of plastic-related waste products, which will be a crucial issue in the future. The reuse of waste and recycled plastic materials in the concrete mix design as an environmentally friendly construction material has drawn the attention of researchers in recent times. (Ghernouli, et al., 2014)

(CEA 2019) revealed that the accumulation of the utilized plastics is a pressing problem, which is considered a major cause of health issues, importantly burning of the plastics, contamination of the soil, water, and air. Further, deterioration of the plastics takes an enormous period of time, and these plastics remain in water bodies, and in soil, which will lead to acute environmental related issues. Recycling

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waste plastics into useful products is one solution to this problem. Many government agencies, private organizations, and individuals have completed or are in the process of completing a wide range of studies and research projects on the feasibility, environmental suitability, and performance of using waste plastics in the construction field, which requires better and more cost-effective construction materials as well as the reuse of waste plastics to save the environment.

(Sandaruwani et al, 2012) identified that similar variation in compressive strength of PET fiber reinforced concrete. Their study revealed that compressive strength increases with increase of fiber content up to a maximum of 1% and then the compressive strength is decreasing with the increment of fiber content more than that. Rathnayaka (2015) conduct an experiment to determine the compressive and tensile strength of PET fiber reinforced concrete and identified that it has been reduced in compressive strength compared to normal concrete but there's an enhancement in tensile strength up to 3% of PET fiber content. However, there is no study on the application of PET flakes with Ordinary Portland Cement (OPC) in concrete road pavements. In addition, several researchers have been carried out preliminary analysis of concrete reinforced and waste polyethylene terephthalate as lightweight aggregate. (N. Saikia and J. de Brito, 2013)

This research paper aims to provide an investigation of the effect of PET flakes as reinforcement material in the Ordinary Portland Cement (OPC) composite. PET plastic bottles, which are extensively used in the Colombo area, were selected as the reinforcing material. During this research work, the material properties, and the effect of PET flakes on the compressive strength of concrete were analyzed. The optimum percentage of recycled plastic has been determined based on an experimental study. The compressive strength of each variant is determined and develop an economically viable concrete mix design using PET flakes. The waste recycled plastic was mixed with OPC mix design by varying proportions (0%, 1%, 2%, 3%, 4%, and 5%) with respect to weight of cement (Saumyasiri & De silva, 2018)

2. AIM AND OBJECTIVES

2.1. Aim

To use Polyethylene Terephthalate (PET) in the concrete structure as inert material and enhance the mechanical properties of concrete.

2.2. Objectives

- To compare the compressive strength of conventional concrete with waste plastic mix (PET flakes) concrete.
- To investigate the optimum PET flakes percentage for mix design

3. METHODOLOGY

3.1 Materials Used

- Clear Color PET (Polyethylene Terephthalate)
- Cement: Ordinary Portland cement (OPC) was used.
- Sand: Manufacture sand which were sieved from 5mm sieve was used.
- Coarse aggregate: 5-20 mm size aggregate was used.

3.2 Pet Flake Concrete Sample Preparation

PET flakes obtained from Viridis Group, Homagama, Sri Lanka was used in the study. PET flakes were added on a weight basis as an inert material. Mix design of concrete was performed according to British (DOE) method (Nevile, 1981). The aggregates were in saturated and surface-dry (SSD) conditions.

3.3 Experimental Procedure

G20 concrete mix was used for these trials. Water-cement ratio was kept constant at 0.55. PET flakes were added as 0%, 1%, 2%, 3%, 4% and 5% of the total weight of the cement content of the mix design as shown in Table 1 to investigate the compressive strength test. The mix design of the concrete mix was illustrated in Table 2.

Table 1: PET Flake Concrete Sample Preparation

Trial No	PET flakes weight (% by weight of cement for 0.025m^3)	Water Cement Ratio
A	0 (Control Sample)	0.55
B	1 (180g)	0.55
C	2 (160g)	0.55
D	3 (240g)	0.55
E	4 (320g)	0.55
F	5 (400g)	0.55

Table 2: Mix Design of The Concrete

Mix Design (1m^3)		For 0.025 m^3
Cement	320 Kg	8 Kg
Water	176 Kg	4.4 Kg
Manufactured Sand	864 Kg	21.6 Kg
Coarse Aggregate	989 Kg	24.73 Kg

The tests of Compressive strength of concrete cubes were performed according to BS EN12390-3:2019 standard, respectively. The load was applied continuously until the specimen failed. Six cubes of (150 mm × 150 mm ×150 mm) specimens were prepared for each mix. The strength of each cube was evaluated after 7, 14 and 28 days, respectively.

Figure 1: Compressive Strength Testing for Cube

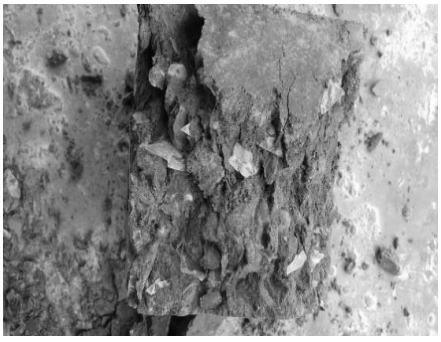

Figure 2: Concrete Cube Specimen in After Testing

4. RESULTS AND DISCUSSION

4.1 Variation of Compressive Strength with PET Flake Content

Table 3 shows the difference in compressive strength of concrete cubes with PET flake content. Three specimens were tested, and the average value was calculated. The compressive strength of 3% PET flakes specimens is found to be greater than that of the control specimen. However, increasing the flake concentration further decreased the compressive strength. The results of the compressive strength test are shown in the line graph below. (Figure 3).

In this study, it is confirmed that adding PET flake to the concrete mixture increased the average compressive strength. The addition of 3% gave the maximum compressive strength, irrespective of the period of cure. It is revealed that with higher PET flake content, the workability of concrete was reduced. However, increasing the PET Flake quantity up to 3%, the compressive strength of concrete shows a sudden decrease compared with control samples.

Table 3: Compressive Strength Results for Concrete Cubes

Compressive Strength Test Results N/mm²						
Percentage of PET flakes	A-0%	B-1%	C-2%	D-3%	E-4%	F-5%
7 Days	14.38	18.49	18.96	19.56	17.02	15.66
14 Days	19.87	24.00	25.95	26.70	23.75	22.02
28 Days	26.00	27.36	30.42	31.22	26.62	25.87

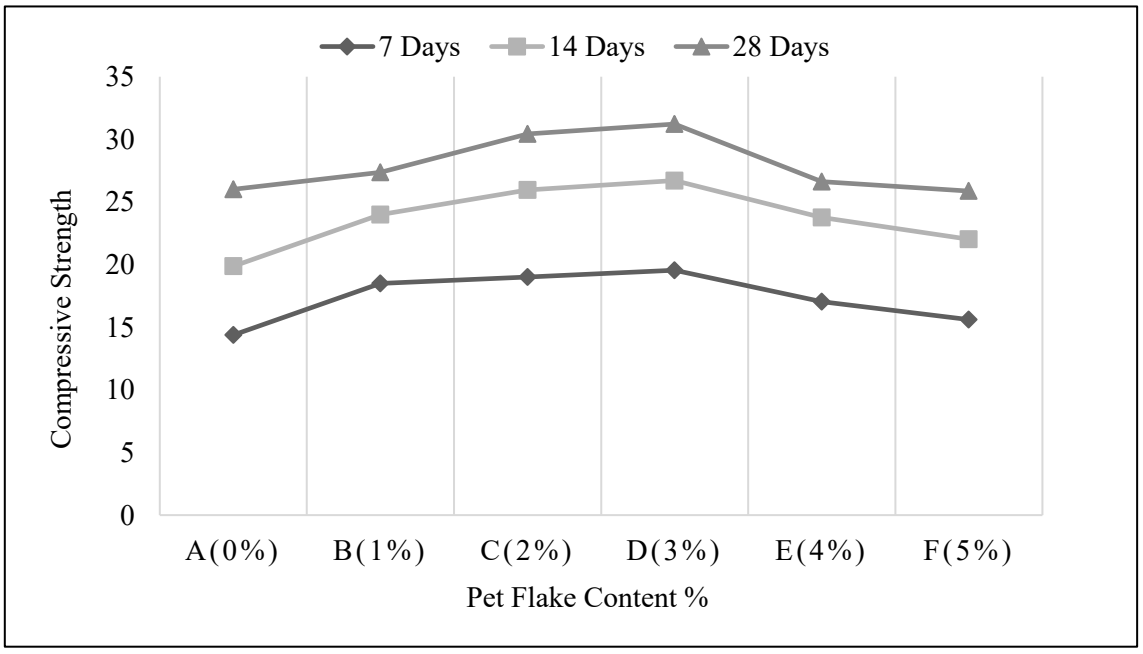

Figure 3: Variation of Compressive Strength with PET Flake Content

4.2 Optimize Mix Design with Optimum PET Flake percentage

From the above observations, 3% PET flake content gives the highest compressive strength results. But this shows that the compressive strength decreases after the plastic exceeds 3%. Two further trials were conducted to make this experiment economically viable. In one mix was tested without PET flakes and in the other only cement was reduced and used 3% PET flakes. There, all other factors were taken to be constant. Comparing the two trial mixes, the compressive strength of 3% PET flake used mix was higher than control mix.

The most commonly used concrete grades by road development authority in Sri Lanka are 20 and 25. Previously used grade20 mix design with normal and economized for road pavement is shown in Table 4.

Table 4: Economize Grade 20 Mix Design

Materials	1st Mix Design without PET(A)	2nd Mix Design with 3% PET(B)
Cement	320Kg	280Kg
Water	154Kg	176Kg
Fine Aggregate	864Kg	864Kg
Coarse Aggregate	989Kg	989Kg
W/C	0.55	0.55
Concrete Density	2349Kg/m3	2287Kg/m3

Compressive Strength of each mix was evaluated after 7, 14 and 28 days, respectively. Figure 4 shows strength details.

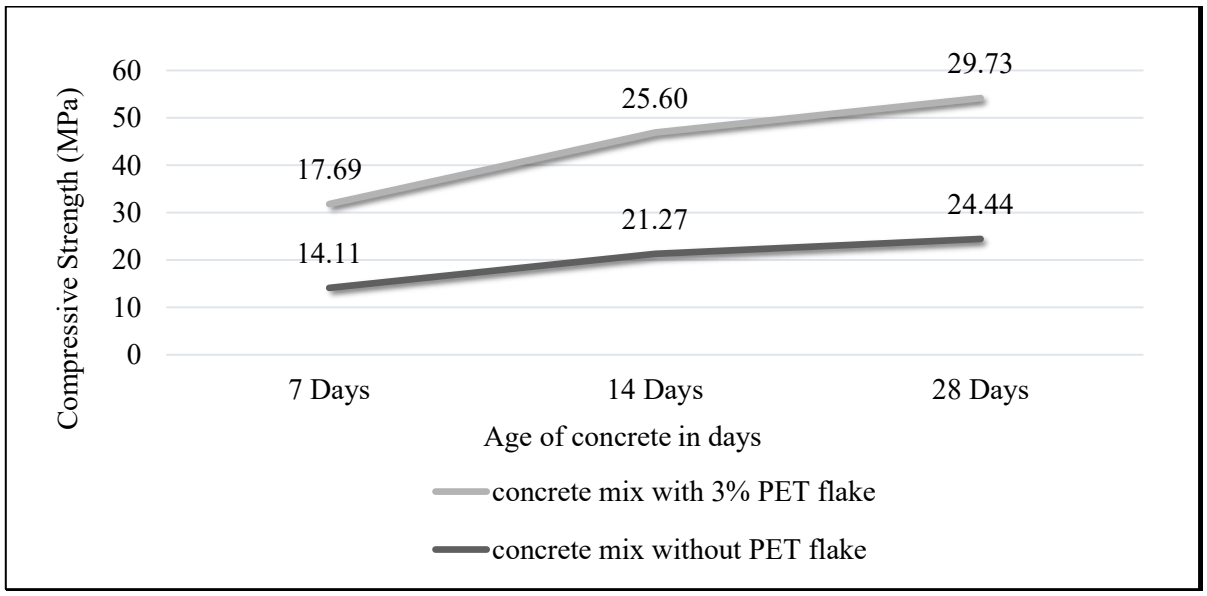

Figure 4: Variation of Compressive Strength with PET Flake Content

According to Figure 4, 3% optimum PET flake concrete sample (B) observed the highest 28 days compressive strength (29.73 MPa) than conventional control sample (A). In addition, by studying this figure can be found that 7 days and 14 days of compressive strength were higher than without PET flake sample. There was significant improvement observed using 3% PET flake with OPC in grade 20 concrete mix design.

5. CONCLUSION

According to the results, this production process, achieves to utilize waste plastic to concrete. By considering the compressive strength of recycled PET flake introduced into concrete and the workability of the mix, 3% PET flake content was found as the optimum value for the design of specimens. Based on the Experimental results, the Compressive strength of concrete is affected by the addition of plastic pieces up to 3% and when it is more than 3%, the compressive strength decreases again.

The ultimate compressive strength for the 3% Recycled PET concrete specimen is higher than the control concrete specimen. As a result, it may be concluded that using plastic in concrete can improve its compressive strength. According to the preceding discussion, it is possible to improve the mechanical properties of concrete by using plastic, which may be used as one of the plastic disposal techniques. 3% optimum PET flake concrete observed the highest 28 days compressive strength (31.22 MPa) without even minor cracks on the concrete surface. Grade 20 concrete was proposed with 0.55 water-cement ratio with 3% PET flakes mix for concrete works as a cost effective and crack minimum concrete. However, further research is needed to better understand the durability of the concrete containing PET flakes.

Furthermore, another important advantage of this research is the ability to create an economical concrete mix design for Grade 20 concrete mix. They were able to reduce the amount of cement in the mix design and considerably reduce the cost per $1m^3$ of concrete. The biggest advantage is that the destruction of the environment from plastic can be minimized.

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