

Reviewing the Effect of Waste PET Strips as Fiber Reinforcement in Concrete

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Abstract

Polyethylene Terephthalate also known as PET is the most commonly and widely used petroleum polymer plastic in the packaging industry. It is a well-established fact that the non-biodegradability of all plastics is a hazard to the environment. Thus, effective management of this waste is necessary. Numerous researchers have carried out studies and attempts to incorporate this plastic waste into concrete for performance enhancement. Considering the possible utilization of this waste in the construction industry, this project is attempting to use this “waste” to strengthen the weakest aspect of concrete, i.e. the tensile and flexural strength of concrete. Fiber reinforced concrete has been gaining popularity in the construction industry for the last few decades over the world. Fiber reinforced concrete not only improves the strength and durability of concrete but also aids in the development of economic designs. The use of strips of recycled PET as fiber reinforced concrete is budding research that aims to achieve multiple sustainable development goals if implemented wisely. This paper is a review of many works carried out in the field of FRC development using PET as fiber reinforcement. Although the overall idea of the implementation of the addition of plastic into concrete appears to be easy and economical, research needs to be done on the current market statistics and trends in the construction industry for determination of actual potential of the idea. The research is valuable for researchers actively working in this field.

Keywords: Fiber reinforced concrete, polyethylene terephthalate fibers, compressive strength, flexural strength, split tensile strength

INTRODUCTION

Polyethylene terephthalate, commonly known as PET is a petrochemical polymer that is produced from the lesser valuable derivatives of fossil fuels. Due to its high recyclability, PET is widely used in various domestic commodity packaging. Although recyclable, the production rates of PET exceed the

recycling rates of PET by a massive difference. This difference gives rise to pollution, as PET is not biodegradable. The discarded unrecycled PET waste goes on filling numerous landfills causing undue loss of land. The methods to produce keep on improving while methods to recycle are yet lacking [1, 2].

Polyethylene terephthalate is a widely utilized plastic found in items like water bottles, food packaging, and textiles. PET is lightweight, durable, and flexible in nature and that makes it important. However, the increasing use of PET has resulted in a global waste management issue, as improper disposal of PET goods has caused massive environmental damage [3]. The recycling of PET is

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crucial in both reducing this problem and as it has the potential of substantially minimizing the amount of plastic that is dumped into landfills and oceans. The recycling of PET involves the collection of PET goods that have been used, converting them into new substances, and thereafter utilizing these substances to produce different goods. However, despite its essentiality, PET recycling faces a variety of challenges restricting it from being effective on an international scale [4]. India recycles or reprocesses on an annual basis around 5.5 million metric tons of plastic waste PW which is around equal to 60% of the total PW put out in the nation. Out of this 70% is recycled through the registered formal units, 20% informally, and 10% at homes.

The other 40% of PW is either uncollected or littered, contributing to pollution in water and land and causing drain blockages. Each year, around 2.5 million tons of PW are sent to landfills, more than 1 million tons are incinerated, and about 0.25 million tons are co-processed as an alternative energy source in blast furnaces by cement companies. Thermoset plastics, such as HDPE, PET, and PVC, which are recyclable, make up 94% of the total PW produced. The remaining 6% consists of non-recyclable plastics, including multilayered plastics and thermocol. While plastics like PP, PS, and LDPE are partially recyclable, they are rarely recycled in India due to the economic challenges associated with their recycling processes. [5] (Figure 1, Figure 2, & Figure 3) shows the detailed breakdown of global plastic waste generation and management. [6]

As PET is non-biodegradable, inert to chemical reactions under normal conditions, strong, and durable, the use of PET as a reinforcing material for concrete to develop an economical and sustainable fibre reinforced concrete mix is an area of interest for many researchers. Fiber reinforced concrete (FRC) incorporating polyethylene terephthalate (PET) fibres have garnered significant attention in recent years due to its potential to enhance the mechanical properties and sustainability of concrete. Numerous studies have investigated the effects of PET fibres on various concrete characteristics, including tensile strength, flexural strength, impact resistance, and durability. Research indicates that the incorporation of PET fibres can improve the post-cracking behavior of concrete, leading to increased toughness and reduced crack propagation. Additionally, PET fibres contribute to the overall ductility of concrete, making it more resilient to dynamic loads. [7] [8]. Investigations have also focused on optimal fibre content and length, revealing that a balance must be maintained to maximize performance without compromising workability. Environmental studies highlight the benefits of utilizing recycled PET fibres, not only to mitigate plastic waste but also to enhance the sustainability of concrete production. Furthermore, experiments on the bonding characteristics between PET fibres and the cement matrix have provided insights into the mechanisms that contribute to improved performance. Overall, the integration of PET fibers in FRC presents a promising avenue for advancing both concrete technology and sustainability practices within the construction industry. [9]

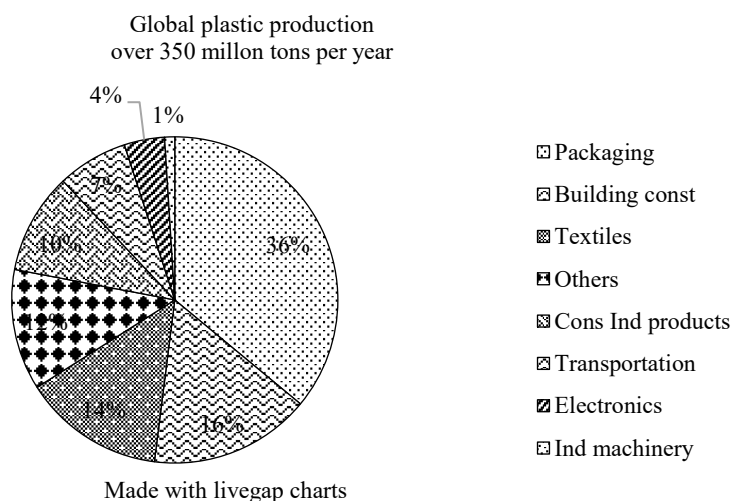


Figure 1. Break down of global plastic production according to the purpose of plastic.

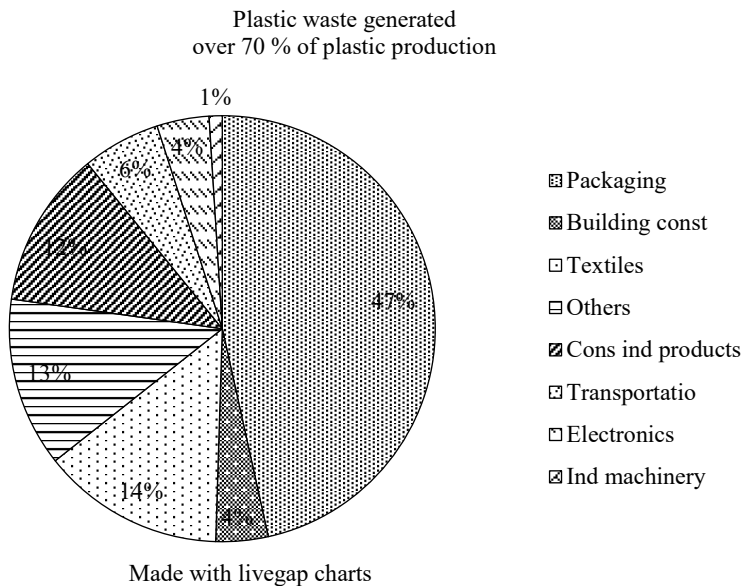


Figure 2. Waste generated after the use of plastic.

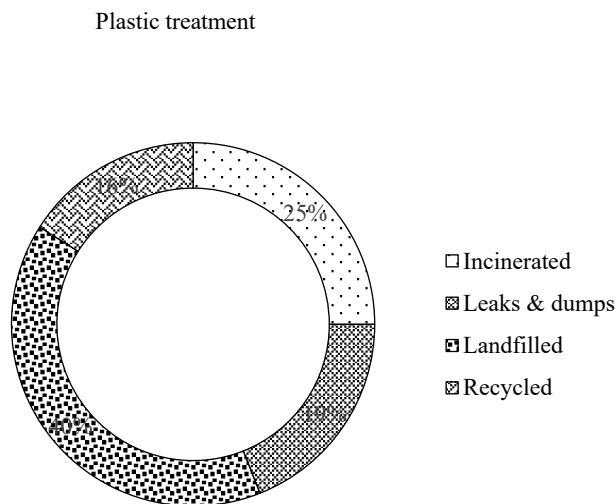


Figure 3. Treatment methods used for disposal of plastic.

Development of PET Fiber-reinforced Concrete

A general methodology adopted by most researchers is represented in (Figure 4). All the crucial tests regarding basic components of concrete i.e. cement, coarse aggregate, and fine aggregate are done to determine the various physical and mechanical properties of the components. Recycled Plastics made from polyethylene such as PET, HDPE, etc. are procured. Then by cleaning any polluting particles on the material, the plastics are modified to change the shape and size to match the research parameters. Some researchers also adopted surface modification of PET as an area of research. Following are tables that summarize the respective mechanical properties of concrete under the area of consideration of the review. (Table 1) shows the summary of compressive strength, (Table 2) shows the summary of Flexural strength, and (Table 3) shows the summary of Split tensile strength of concrete after utilization of waste plastic.

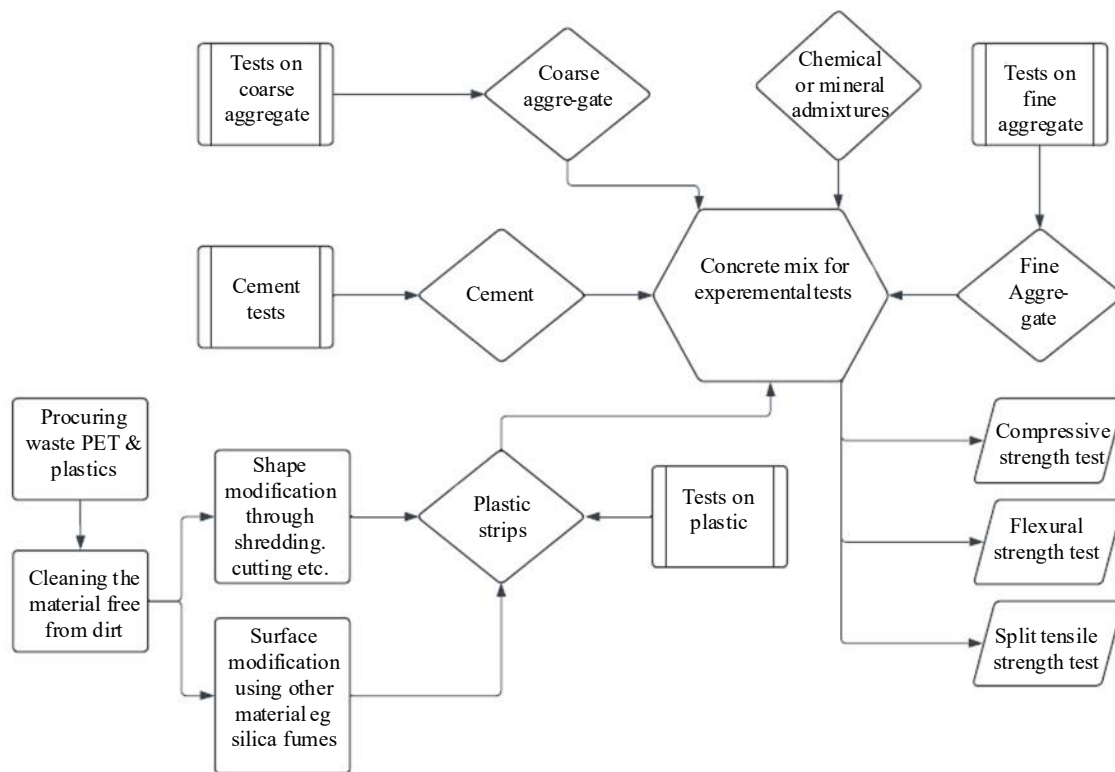


Figure 4. Flow chart of general methodology adopted for research.

Table 1. Comparison of compressive strength of Plastic Fiber Reinforced Concrete.

Source	Shape and Size of specimen(mm)	Form/size of plastic added	Type of plastic	Replaced component	Replaced/Added quantity	Grade of concrete and Curing condition	Result	Ranges	Optimum strength @ %
Robert Haigh [10]	Cylinder 100 x 200	Shredding(3 x 3) 1. Normal, 2. Surface modified	HDPE	Cement	10%(by wt. of cement)	25MPaC-28D	16% increase in CS with SF coating on	-	-
Yara Mounaet al. [11]	Cube 150 x 150 x 150	Straight strips(25 x 4,40 x 4,50 x 4)	PET	-	0.5%, 1%(by volume of concrete)	M50IC-28D (20+3°C)	4% increase in CS (for 40mm L-0.5% mix)	0.5-1%	0.5%, 1%
Trong-Phuoc Huynh et al. [12]	Cube 100 x 100 x 100	Straight strips(30 x 2,50 x 470 x 6)	PET	-	0.3%, 0.45%, 0.6%(by volume of concrete)	IC-58D	12.9% increase in CS	0.3-0.6%	0.45%
NZ Nkomoet al. [13]	Cube 150 x 150 x 150	Microfiber 1 2mm L, 18µm d	PET	-	0.5%, 1%, 1.5%, 2%(by wt. of dry concrete)	M20IC-28D (23+3°C)	23% increase in CS	0.5-2%	0.5%

Fernando Pelissera et al. [23]	Cylinder 100 x 200	Straight strips 10, 15, 20mm L, 25-30mm d	PET	-	0.05%, 0.18%, 0.30% (by volume of concrete)	29 MPa IC-28D	No change in CS	0.05-0.3%	-
Ruben Paul Borg et al. [22]	Cube 150 x 150 x 150	Straight, deformed strips (50 x 2, 30 x 2)	PET	-	0.5%, 1.0%, 1.5% (by volume of concrete)	30 MPa 21°C	0.5%-8.5% reduction in CS	0.5-1.5%	-
Ninoslav Pešić et al. [21]	Cube 100 x 100 x 100	23mm L, 0.25mm d, 23mm L, 0.40mm d	HDPE	-	0.4%, 0.75%, 1.25% (by volume of concrete)	C25/30 class IC-90D	No change in CS	-	-
P. Savoikar et al. [20]	Cube 100 x 100 x 100	PET (fragments), HDPE (pellets shredding), PP (fibers, strips)	PET, HDPE, PP	Fine Aggregate	10% (by wt. of FA)	53 MPa IC-14D	1.5% increase in CS	-	0.64% PP Fiber(20mm)
SS. Asadi et al. [19]	Cube 150 x 150 x 150	Shredded flakes (less than 10 mm)	PET	Fine Aggregate	5%, 10%, 15%, 20% (by wt. of FA)	M20, M25, M30 IC-28D	10% increase in CS	0-20%	10% replacement
Azad A. Mohammed et al. [18]	Cylinder 150 x 300	20 mm L 40 mm L	PET	-	0.75%, 1% (by volume of concrete)	90 MPa	Approx. 30% reduction in CS	0.75-1%	-
Lisa Mary Thomas et al. [17]	Cube 150 x 150 x 150	50 x 2.3 (0.25mm Thick)	PET	-	0.2%, 0.4%, 0.6%, 0.8% (by volume of concrete)	M50 IC-28D (27±2°C)	10.67% increase in CS	0.2-0.8%	0.4%
Mohammed Belmokaddem et al. [16]	Cube 100 x 100 x 100	Fine or medium aggregate 0-3 mm, 3-8 mm	PP, HDPE, PVC	Fine and Coarse aggregates	25%, 50%, 75% (by volume of concrete)	-	Decrease in CS with increase in plastic	25-75%	-
Sandeep Salhotra et al. [15]	Cube 150 x 150 x 150	Straight strips 1. Uncoated 2. Coated with SF (50 x 2, 3)	PET	-	3%, 6%, 9%, 12% (by wt. of cement)	M40 IC-28D	SF coated PET fibers mix shows no	3-12%	-
Alejandro Meza et al. [14]	Cylinder 100 x 200	Straight strips (53.5 x 3, 85.6 x 3, 117.8 x 3) (0.3mm)	PET	-	2 kg/m ³ , 6 kg/m ³ , 10 kg/m ³	30MPa IC-28D	9% decrease in CS	-	Mix with (10kg/m ³ and 117.8 x

PE – Polyethylene, PET - Polyethylene Terephthalate, HDPE -High Density Polyethylene, PVC - Polyvinyl Chloride, PP- Polypropylene, CS – Compressive Strength IC- Immersion Curing, FA - Fine Aggregate, L – Length, d – Diameter, SF – Silica fume

Table 2. Comparison of flexural strength of Plastic Fiber Reinforced Concrete.

Source	Test Performed	Shape and Size of specimen (mm)	Form/size of plastic added	Type of plastic	Replaced component	Replaced/A dded Quantity	Grade of concrete and Curing condition	Result	Ranges	Optimum Strength @ %
Robert Haigh [10]	Four Point Loading	Cylinder 100 x 200	Shredding (3 x 3) 1. Normal, 2. Surface	HDPE	Cement	10% (by wt. of cement)	25MPa IC-28D	FS of SFPMB was equal to control mix	-	-
Yara Mounaet al. [11]	Four Point Loading	Cube 150 x 150	Straight strips (2.5 x 4, 40 x 4, 50 x 4)	PET	-	0.5%, 1% (by volume of concrete)	M50 IC-28D (20+3°C)	4% increase in flexural strength	0.5-1%	0.5%, 1%
Trong-Phuoc Huynh et al.	-	Cube 100 x 100	Straight strips (30 x 2, 50 x 4, 70 x 6)	PET	-	0.3%, 0.45%, 0.6% (by volume of concrete)	-IC-58D	33.1% increase in flexural strength	0.3-0.6%	0.45%
NZ Nkomo et al [13]	Four Point Loading	Beam 150 x 150	Fibers L=12mm, d=18µm	PET	-	0.5%, 1.0%, 1.5%, 2.0% (by wt. of dry concrete)	M20	FS increased by 27%	0.5%-	0.5%
Alejandro Meza et al [14]	Three Point	Beam 150 x 150 x 500	Straight strips (53.5 x 385.6 x	PET	-	2Kg/m ³ , 6kg/m ³ , 10Kg/m ³ of	30MPa IC 28D	FS of control mix and 10kg/m ³	-	-
Sandeep Salhotra et al [15]	-	Beam 100 x 100 x 500	Straight strips, 1. Uncoated, 2. Coated	PET	-	3.0%, 6.0%, 9.0%, 12.0% (by wt. of	M40 IC 28D	FS of all FRC mixes was less than CM.	3.0%-12.0%	50mm Coated 13.0%
Lisa Mary et al [17]	-	Beam 150 x 150 x 500	Straight Fibers 50 x 2.3 Thickness=	PET	-	0.2%, 0.4%, 0.6%, 0.8% (by wt. of cement)	M50 IC 28D	0.4% binary FRC gives 35.6% increase in	0.2%-0.8%	0.4%
SS. ASADI et al [19]	Three Point	Beam 100 x 100 x 500	Shredded flakes are less than 10mm	PET	Fine Aggregate	5%, 10%, 15%, 20% (by weight of FA)	M20, M25, M30 IC 28D	FS is increased up to 10% in all	5%-20%	10%
Ruben Paul Borg et al [22]	Three Point	Beam 150 x 150 x 550	Deformed and straight strips	PET	-	0.5%, 1.0%, 1.5% (by vol. of concrete)	30 MPa IC 28D	FRC endure higher peak load	0.5%-	-
Fernando. Pelissera et al [23]	Three Point	Beam 150 x 150 x 500	Straight fibers (L=20mm d=25-	PET	-	0.05, 0.18, 0.30% (by vol. of concrete)	29 MPa IC 28D	19% increase in FS	0.05%-	0.30%

PE – Polyethylene, PET - Polyethylene Terephthalate, HDPE -High Density Polyethylene, FS – Flexural Strength, SF – Silica Fume, L -Length, r -Replacement, d -Diameter, IC -Immersion Curing, D -Days, FRC -Fiber Reinforced Concrete, CM - Control mix Concrete

Table 3. Comparison of split tensile strength of Plastic Fiber Reinforced Concrete.

Source	Shape and Size of specimen (mm)	Form/size of plastic added	Type of plastic	Replaced component	Replaced/Added Quantity	Grade of concrete and Curing condition	Result	Ranges	Optimum Strength @ %
Robert Haigh [10]	Cylinder 100 × 200	Shredding (3x3) 1. Normal, 2. Surface modified using SF	HDPE	Cement	10% (by wt. of cement)	25MPa IC-28D	16.6% increase in STS with SF modified	-	-
NZ Nkomoet al. [13]	Cylinder	Micro fiber 12mm L, 18µm d	PET	-	0.5%, 1%, 1.5%, 2% (by wt. of dry concrete)	M20 IC-28D (23+3°C)	11% decrease in STS for 0.5% mix.	0.5-2%	-
Alejandro Meza et al. [14]	Cylinder 150 x 300	Straight strips (53.5 x 3, 85.6 x 3, 117.8 x 3) (0.3mm Thick)	PET	-	2 kg/m ³ , 6 kg/m ³ , 10 kg/m ³	30MPa IC-28D	11.5% increase in TS.	-	Mix with (10kg/m ³ and 117.8 x
Sandeep Salhotra et al. [15]	Cylinder 150 × 300	Straight strips 1. Uncoated 2. Coated with SF (50 x 2, 100 x 2, 150 x 2)	PET	-	3%, 6%, 9%, 12% (by wt. of cement)	M40 IC-28D	SF coated PET fibers (6% mix) show a	3-12%	6%
Lisa Mary Thomas et al. [17]	Cylinder 150 × 300	50 x 2.3 (0.25mm Thick)	PET	-	0.2%, 0.4%, 0.6%, 0.8% (by volume of concrete)	M50 IC-28D (27± 2°C)	84.6% increase in STS	0.2-0.8%	0.4%
Azad A. Mohammed et al. [18]	Cylinder 150 x 300	20 mm L, 40 mm L	PET	-	0.75%, 1% (by volume of concrete)	90 MPa	STS decreased in all mixes with a	0.75-1%	-
SS. Asadiet al. [19]	Cylinder -	Shredded flakes (less than 10 mm)	PET	Fine Aggregate	5%, 10%, 15%, 20% (by wt. of FA)	M20, M25, M30 IC-28D	10% increase in STS	0-20%	10% replacement
P. Savoikar et al. [20]	Cylinder 100mm-d	PET (fragments), HDPE (pellets shredding), PP (fibers, strips)	PET, HDPE, PP	Fine Aggregate	10% (by wt. of FA)	53 MPa IC-14D	25% increase in STS	-	-
Ninoslav Pešić et al. [21]	Cylinder 100 × 200	23mm L, 0.25mm d, 23mm L, 0.40mm d	HDPE	-	0.4%, 0.75%, 1.25% (by volume of concrete)	C25/30 class IC-90D	No substantial increase in STS	-	-

PE – Polyethylene, PET - Polyethylene Terephthalate, HDPE -High-Density Polyethylene, PVC - Polyvinyl Chloride, PP- Polypropylene, STS- Split Tensile Strength, IC- Immersion Curing, FA - Fine Aggregate, L – Length, d – Diameter, SF – Silica fume.

COMPARISON OF RESULTS

Compressive Strength of FRC using Recycled Plastic

As displayed in Table 1 the compressive strength of FRC is observed to be increased in the majority of the reference papers [10-13, 17, 19, 20] with a maximum increase of 23%. The increase in the compressive strength occurs generally in the form of a bell-shaped curve with a gradual increase to a peak maximum and then a fall. In some cases, the compressive strength decreased [14,16,18,22], with a maximum reduction of 30%. The comparative results of control mixes and experimental FRC are shown in Figure 5. Excess plastic in concrete resulted in a decrease in compressive strength as plastic occupies more space than required in the matrix, hindering the uniformity of cement water coating on the aggregates. Although a critical amount of plastic reinforces the matrix by bonding with the cement and holding the aggregates together to some extent.

As compressive strength is the definitive property of concrete, the quantity of plastic added must not affect the compressive strength negatively.

Flexural Strength of FRC Using Recycled Plastic

Table 2 shows the key findings in the referred research papers related to flexural strength. Although FRCs are mainly implemented for better performance of concrete, fewer instances of flexural strength testing are seen as the research is mainly done with the aim of implementing Plastic waste in concrete to reduce plastic pollution. However, research shows that the majority of the time, flexural strength is improved by the addition of PET. The highest increase in Flexural strength is seen at 35.6%. While the flexural strength increased in the majority of the referred results [11- 14, 17, 19, 23], other results show the same or comparable flexural strength to the control mix [15]. Fig. 6 shows a graphical interpretation of the data.

Fibers, when distributed evenly along the concrete mix, are bound to increase the flexural strength of the member by dispersing the flexural load over a larger area in the concrete and providing its own tensile strength to the member.

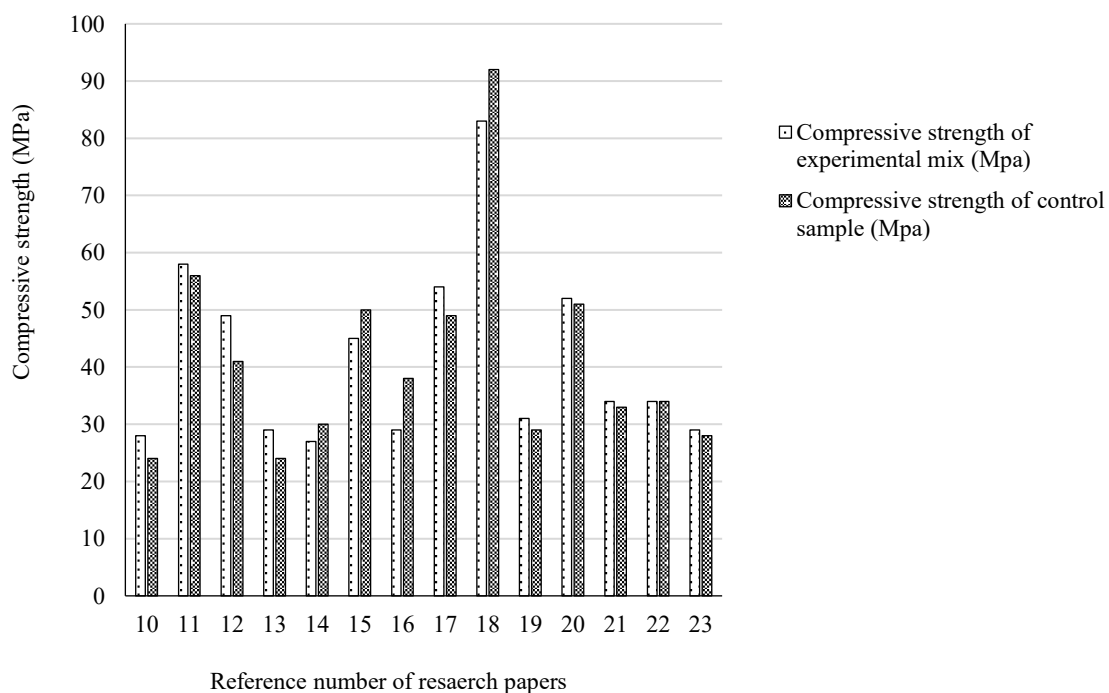


Figure 5. Comparison of Flexural strength results in referred research papers. [10-23]

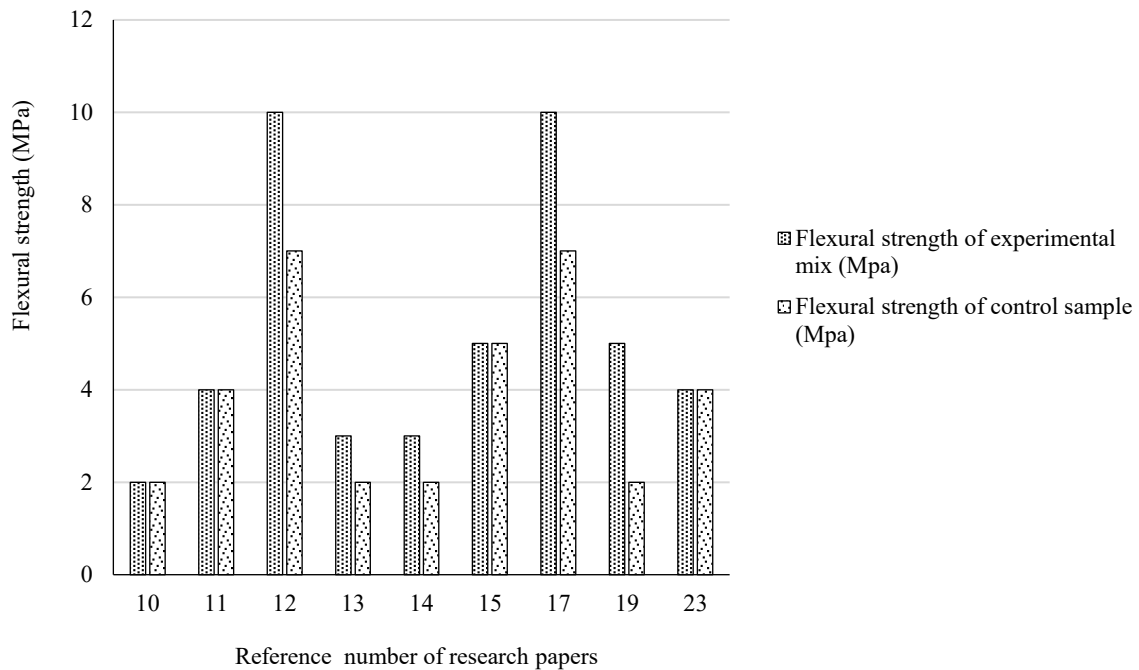


Figure 6. Comparison of Flexural strength results in referred research papers. [10- 15, 17, 19, 23].

Split Tensile Strength of FRC Using Recycled Plastic

Split tensile strength is the capacity of the concrete to sustain the squeezing action of forces acting on the member. Similar to the flexural strength, uniform dispersion of fibers causes an increase in the majority of the studies referred to as [10, 15, 17, 19- 21] show an increase in STS. The highest increase of 84.6% was seen by the addition of PET fibers. Instances of decreased performance in STS [13, 14, 18] are seen with the lowest of 11%. Figure 7 shows a graphical interpretation of the data shown in Table 3.

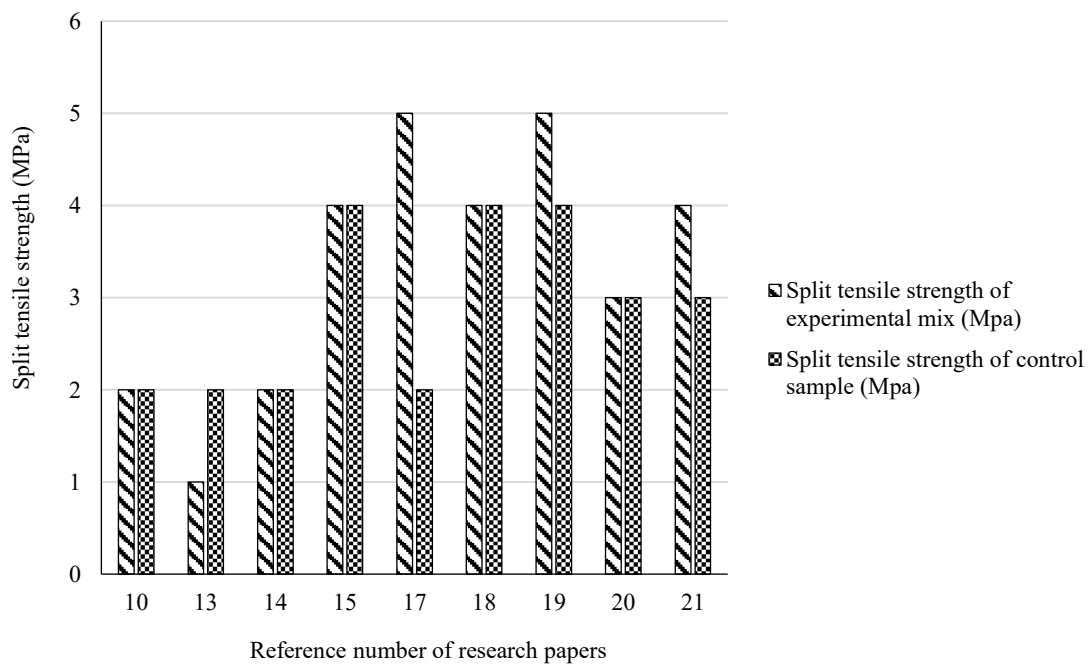


Figure 7. Comparison of split tensile strength results in referred research papers. [10, 13-15, 17-21].

DISCUSSIONS

The surface modification technique employed in this study, using silica fume (SF) as a coating on plastic fibers, effectively enhanced the bonding between waste plastic fibers and the concrete matrix. This modification significantly improved the mechanical properties of concrete, particularly in compressive strength, and presented a sustainable alternative to cement in the concrete mix. Integrating SF with plastic fibers in concrete results in improved mechanical properties [10]. There was a noticeable growth in the compressive, tensile, and flexural strengths of the sample. The reason for the lower percentage improvements for this study was attributed to the differences noted for the inclusion of SF and the proportion of plastic used.

Moreover, consideration should also be given to the fact that the additional surface area provided by SF particles compared to cement plays an important function in the increase of compressive strength. SF combines calcium oxide and compounds in the mix to form a gel that fills in the concrete’s voids and increases its density and strength. This is true because SF strengthens the loading of the particles and the building of silicate calcium compounds which are important for the development of strength.[10]

In concrete, aspects such as the shape and dispersal of plastic fiber determine its strength. For this current paper, the use of smaller-sized fibbers which were randomly dispersed was employed. This is probably a reason why this paper’s findings vary from other studies with the use of longer or regularly shaped fibers.[13] The beneficial role of fibber length and its aspect ratio on tensile strength and flexural strength of concrete has been well documented. In particular, fibers with a higher aspect ratio improve the distribution of load within the concrete matrix, thus enhancing both tensile and flexural strength [11, 14].

However, while the addition of plastic fibers does offer improvements in certain mechanical properties, such as tensile strength, the results in flexural strength were less pronounced. This observation could be attributed to the fact that SF's primary benefit is in increasing the packing density and enhancing compressive strength, rather than improving the bonding for tensile and flexural properties. Previous studies have similarly shown that the integration of fibrous materials tends to increase tensile strength more effectively than flexural strength [15, 17]. For a quick glance of replacement percentage adopted for research in referred works, Figure 8 shows a graphical representation of reference number v/s amount of fibers added in concrete.

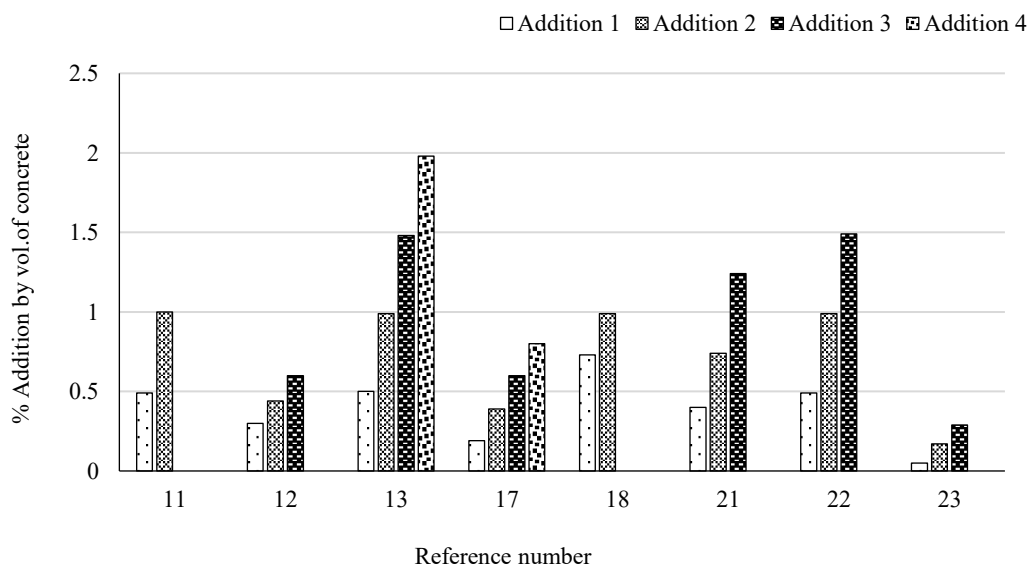


Figure 8. Variation of fiber quantity in reference papers [11-13, 17, 18, 21-23].

Another key factor observed was the impact of fiber content on workability. Increasing the volume fraction of plastic fibers generally results in a reduction in workability, as seen in the referred material. Mixing uniformity is difficult to achieve due to the reduction of workability caused by higher fiber contents, so it is important to set optimal levels of workability which are usually less than 1%.

Apart from the tensile strength of concrete composites with plastic fibers, the authors focused on durability aspects too. Together with a decrease in water absorption, there is an increase in the rate of ultrasonic pulse velocity (UPV) in the modified fiber samples and due to these fibers, now matrix bonding is strengthened within the cement rather than only relying on concrete making these test samples have much more durable characteristics than before. This research confirms the conclusions drawn in earlier papers that the internal structure of the fibers, for instance, their length and diameter, have a significant influence on water absorption and other durability characteristics of the fiber-reinforced concrete [10, 12, 17, 19].

As a result, using waste plastic in concrete mixes has positive environmental aspects. Sending plastic waste to landfills is costly and extraction of commercial sand also has a negative impact on the environment, but by using plastic fibers that have already been recycled, Ready-mix can address both these issues. The results confirm the effectiveness of waste plastic fibers for partial substitution of cement and fine aggregates in concrete providing a more environmentally friendly construction material and also contributing to waste minimization. In conclusion, the surface modification of plastic fibers with SF has demonstrated substantial potential for improving the mechanical properties and durability of concrete. Future studies should focus on optimizing the fiber content, aspect ratio, and the interaction between modified fibers and the cement matrix to further enhance the performance and sustainability of these concrete mixtures.

CONCLUSIONS

Based on the above comparisons and simplification of the key findings of the referred research papers, the following conclusions can be safely drawn:

1. The addition of PET in certain amounts and shapes as reinforcing fibers yields to overall increased performance of concrete. However, the shape and amount of plastic can be specified only after experimenting and testing of designed concrete.
2. PET is cheaper to produce and expensive as well as complex to recycle chemically, thus the mechanical modification of PET into fibers is comparatively easy and economical.
3. The addition of waste plastics and PET into concrete can save a lot of usable land that is occupied by these non-biodegradable products in landfills and dump yards saving the cost and quality of land.
4. Based on the referred material, the quantity of fibers advisable can be taken as 0.2% to 1.00% by the volume of concrete produced.
5. The range for the size of the fibers can be narrowed down, based on the referred research to follow an aspect ratio of (Length: equivalent diameter) 20 to 60 for optimum results.
6. The workability of concrete is seen to be decreasing with the increase of fiber content, thus appropriate addition of admixtures is observed and advised.
7. No specific or uniform pattern of variation in results is seen, thus indicating the need for experimental verification strength of fresh and hardened FRC using plastic waste after design for evaluation and assessment actual performance of the concrete.
8. Surface modification of the plastic is observed and advised using cementitious materials such as silica fumes for increment in the bonding of fibers with the concrete matrix. Surface-modified plastic is also observed to yield better results than normal plastic.
9. PET has a unit density slightly higher than water but significantly lower than other components of concrete, thus mixing of the FRC must be done with proper precautions.
10. Research can be conducted on the improvement of bonding the plastic with concrete matrix.
11. Although the overall idea of the implementation of the addition of plastic into concrete appears to be easy and economical, research needs to be done on the current market statistics and trends in the construction industry to determine of actual potential of the idea.

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