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Mechanical Behavior of Concrete by Partial Replacement of Cement with Silica Fume and Polypropylene Fibers: An Analytical Approach

Research Scholar Kalvala Abhiram, Assistant Professor Dr. G. Prashanth
Department of Civil Engineering,
Chaitanya Deemed to be University,
Warangal, TS, India

Abstract- Fibre and PET are now being researched for use in reinforcing reinforced concrete members all over the world.PET bottles are the by-products of storing cold beverages, drinks, or even water. On the other hand, super high strength with high performance is becoming the order of the day in order to construct structures that are durable, environmentally conscious, and even cost effective. These days, composite materials are being developed to meet the needs of the building industry by providing more flexible and durable concrete. The makers and consumers of plastic face a significant issue in disposing of plastics in any form. In today's scenario, the production of environmentally friendly plastics has not yet reached its pinnacle. This is an attempt to dispose of the same effectively by including it as an effective component in concrete. Because of its improved strength, crushed PET bottles have found their way into concrete as a replacement for fine and coarse materials. PET bottles, fine aggregate, and polypropylene fibre have been used to improve the tensile property of M35 grade concrete in order to make it more effective, light weight, and efficient. In this investigation, the mechanical properties of the concrete were investigated, as well as the performance of the concrete.

Keywords- PET (Polyethylene Terephthalate), Polypropylene fibres, Fine aggregate, Durable, Flexible replacement, Compressive strength, Split tensile strength, Flexural strength.

I. INTRODUCTION

Decomposition of any plastic, regardless of type, takes several years (20-30 years in most cases). Many attempts have been made, and more are being undertaken, to develop effective ways to dispose of plastics. Polymers such as Polypropylene and Polyethylene terephthalate are the most commonly used to produce plastic products. The uncontrolled production of plastics in modern times even after the ban was put in place, there is a need to find an effective disposal system. Another effective method identified is the use of contaminated plastic in construction materials. Therefore, an attempt to convert building materials into fine batches using contaminated plastics especially the more available plastics such as Polypropylene and Polyethylene terephthalate.

The main objectives of the project are
- To find the material properties constituted in concrete.
- To observe the strength parameters of concrete by using plastic wastes, fibers.
- Identification of high content of plastic waste (PET) and fiber (PP) to be added to concrete.

II. INGREDIENTS

- Cement : OPC 53 grade
- Fine aggregate : Manufactured sand (M sand), Polyethylene Terephthalate (PT) (Recycled Plastic)
- Coarse aggregate : Gravel or Stone powder (crushed stone).
- Fiber : PP fibre (Aspect ratio 200).
- Water : Normal potable water.
- Admixture : Silica Fume.

1. Polypropylene Fibres:

Polypropylene fibres are synthetic fibres derived from petroleum products, and are used in concrete and mortar to overcome concrete deficiencies.

Fig 1. Polypropylene Fibre.

Table 1. Water Absorption.

Materials	Water absorption in % after 24hrs
PP fibers	0.3
Polyethylene terephthalate	0.1
F.A	1.2
C.A	1.38

Table 2. Polyethylene Terephthalate Properties.

Properties	Values
Density(gm/cm^3)	1.3 - 1.4
Coefficient of thermal expansion (x10^{-6}K-1)	20 - 80
working temperature Lower limit (°C)	-40 to -60
working temperature Upper limit (°C)	115 - 170

Table 3. Physical Characteristics of Polypropylene Fibre.

Property	Value
Length (mm)	12
Diameter (mm)	0.034
Young's Modulus (MPa)	2800
Melting point (C^0)	160
Burning point (C^0)	590

III. RESULTS AND DISCUSSION

1. Compressive Strength:

Fig 2. Uniaxial Compressive Strength Test Setup.

For compressive strength, 15cm x 15cm x 15cm cubes has been tested. The cubes tested have been cured 28 days in normal potable water under normal room temperature. For trail mix combination, three cubes were tested with 28 days of healing using a compression test machine as shown in Figure 2 and the test results are shown in Tables 4 & 5.

Table 4. Effects of PET & Fibre Concrete under Pressure.

Mix Designation	Load (kn)	Compressive Strength @ 28 days (MPa)
M0P0	700.20	31.12
M1P10	666.20	29.61
M2P20	652.06	28.98
M3P30	667.30	29.66
M4P40	617.16	27.43

Table 5. Test results of Silica fume Concrete.

Mix Design	Load (kn)	Compressive Strength @ 28 days (MPa)
M0P0S15	702.39	31.21
M1P10S15	699.51	31.09
M2P20S15	701.29	31.16
M3P30S15	702.48	31.23
M4P40S15	701.78	31.18

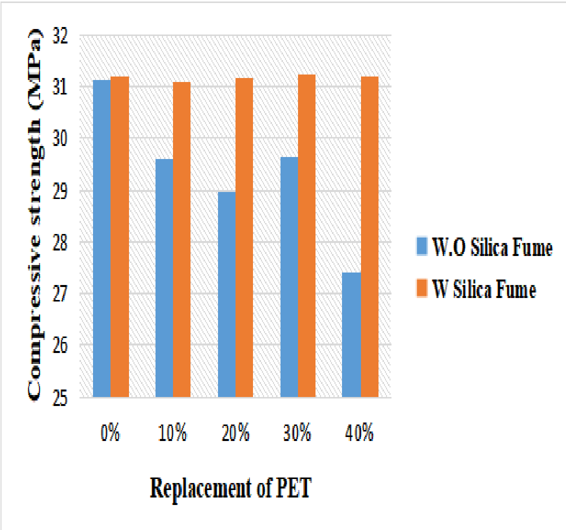

Fig 3. Compressive Strength at 28 days.

Table 6. Percentage of Strength increased

Mix Design	% of Strength Increased
M0P0 - M0P0S15	0.33%
M1P10 - M1P10S15	6.0%
M2P20 - M2P20S15	7.56%
M3P30 - M3P30S15	5.27%
M4P40 - M4P40S15	13.72%

2. Split Tensile Strength:

Indirect rigid strength or Split tensile strength test was tested on cylindrical diameters 150 mm wide and 300 mm long by curing the for 28 days in plain water using a pressure gauge as shown in Figure 4 and test results shown Tables 7 & 8.

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$F_t = 2P / (3.14 \times (DL))$

Where,
F_t - Split tensile strength of the specimen in (MPa)
P - Maximum load applied to the specimen (N)
D - Diameter of the specimen (mm)
L - Length of the specimen (mm)

Fig 4. Tensile Strength Test Setup.

Table 7. Strength results of PET & Fibre Concrete under Tension.

Mix Designation	Load (kn)	Tensile Strength @ 28 days (MPa)
M0P0	269.78	3.81
M1P10	193.59	2.73
M2P20	170.87	2.41
M3P30	149.09	2.10
M4P40	139.98	1.97

Table 8. Results of Silica Fume Concrete.

Mix Designation	Load (kn)	Tensile Strength @ 28 days (MPa)
M0P0S15	272.71	3.86
M1P10S15	198.52	2.81
M2P20S15	176.77	2.502
M3P30S15	154.72	2.19
M4P40S15	141.37	2.001

Table 9. Percentage of Strength Increase.

Mix Design	% of Strength Increased
M0P0 - M0P0S15	1.06%
M1P10 - M1P10S15	3.0%
M2P20 - M2P20S15	3.38%
M3P30 - M3P30S15	3.89%
M4P40 - M4P40S15	1.07%

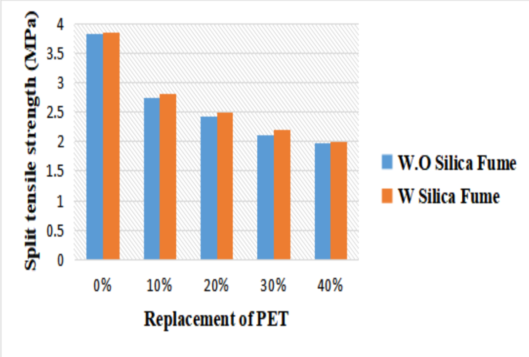

Fig 5. Split Tensile Strength Results.

3. Flexural Strength:
Concrete prisms size 100mm x 100mm x 500 mm were used to determine the bending strength of the weak concrete in compression. The set test includes a central loading or so-called third point loading. The template is set as shown in Figure 6 on a test machine which is a reliable and competent test type. Findings are represented in Tables 10 & 11.

Flexural strength = (P x L) / (B x D²)

$$\text{Flexural strength} = (P \times L) / (B \times D^2)$$

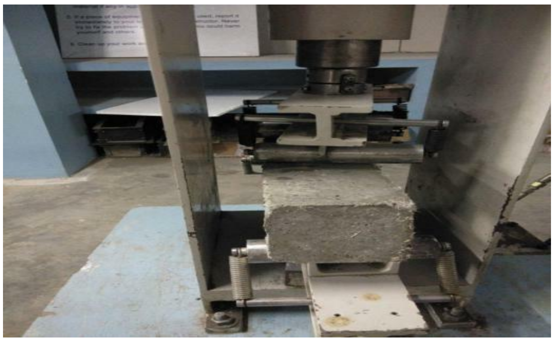

Fig 6. Test Setup for Flexural Loading.

Table 10. Strength Results of PET & Fibre concrete under Flexure.

Mix Designation	Load (kn)	Flexural Strength (MPa) @ 28 days
M0P0	10.98	5.49
M1P10	9.04	4.52
M2P20	8.84	4.42
M3P30	9.94	4.97
M4P40	8.92	4.46

Table 11. Test results of Silica fume Concrete.

Mix Designation	Load (kn)	Flexural Strength (MPa) @ 28 days
M0P0S15	11.06	5.529
M1P10S15	10.84	5.42
M2P20S15	10.54	5.27
M3P30S15	10.18	5.09
M4P40S15	9.46	4.73

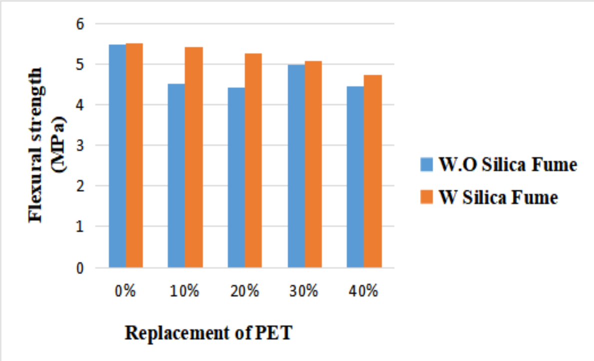

Fig 7. Flexural Strength at 28 days.

Table 12. Percentage of Strength Increase.

Mix Designation	% of Strength Increase
M0P0 - M0P0S15	0.71%
M1P10 - M1P10S15	18%
M2P20 - M2P20S15	16.68%
M3P30 - M3P30S15	2.38%
M4P40 - M4P40S15	5.87%

IV. CONCLUSION

Comparing the results of tests of compact strength of conventional concrete, fibre-reinforced concrete and silica-cement concrete, it was clear that the compressive strength increased to 31.221MPa in silica fume concrete while the results of standard-strength concrete and fibre found were 31.12 and 29.66 MPa respectively.

Similarly the strong separation strength that adds PET as a solid aggregate and PPA as a concrete in concrete shows the indirect strength of 2.74MPa and 3.82 MPa respectively while silica smoke as a concrete mixture increases the strength to 3.86 MPa. The reason for the improvement is because of the thick silica smoke that fills small holes in the concrete and makes the concrete very dense. The flexible strength of PET concrete and fibre reinforced concrete is 4.97 MPa and 5.49 MPa while silica concrete added concrete to 5.529 MPa. It shows that added concrete with admixtures will increase the flexibility to improve the entire concrete surface. Initially Silica Fume added concrete and fibres proving that it has a great need to improve the mechanical properties of concrete and thus make the concrete stable and durable. Dirty plastics and mixtures can therefore be used effectively in concrete to produce effective and economical concrete.

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