

Effects of Surface Treatment of Polyester Fibre on Properties of Concrete

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ABSTRACT: Polyethylene terephthalate (PET) fibres have been used in fibre reinforced concrete, but poor dispensability of PET, due to low wettability, cause reduces strength of the reinforced concrete. However, the hydrophobic nature of PET surface results poor wettability with ionic surface of cement, sand and other concrete admixture, proper bonding between the hydrophobic PET and hydrophilic cement matrix is possible with surface modification of polyester fibre. In present work attempts to modify the PET fibre surface by chemical treatment at ambient temperature and to see the effects on compressive strength, split tensile strength and flexural strength of concrete. Comparisons have been done between all these materials. PET fibres with different level of reinforcement index were investigated with pre-designed concrete mix of M₂₅ grade, consisting of various PET dosages.

KEYWORDS: PET fibre, Surface treatment, FTIR, Compressive strength, Split tensile strength, Flexural strength, Cement, Coarse Aggregate, Fine Aggregate.

I. INTRODUCTION

In the recent years Polyethylene terephthalate (PET) fibre has been used in concrete because of the unique advantage such as low cost of raw material. Generally, strong fibre-matrix interfacial bonding arises when proper wetting of the fibre surface, mechanical interlocking and the formation of strong chemical bonds between the fibres and cementitious matrices are poor because of low wettability of PET fibre [1, 2]. Low tensile strength is one disadvantage of concrete despite its high compressive strength. When subjected to tensile stresses, unreinforced concrete will crack and fail easily. Based on previous studies, fibre reinforcing increases tensile loading capacity and improves properties such as fracture toughness, ductility, crack-width control, and make it light weight per unit volume[3]. The development of secondary reinforcement in Concrete in various fields has provided a strong technical base for improving the quality of the material. To overcome these deficiencies, fibres are used as secondary reinforcement. The choice of fibres varies from synthetic organic materials such as polypropylene or carbon, synthetic inorganic such as steel or glass, natural organic such as cellulose or sisal to natural inorganic asbestos. The selection of the type of fibres is guided by the properties of the fibres such as diameter, specific gravity, Young's modulus, tensile strength etc with the extent these fibres affect the properties of the cement matrix[4].

In present work attempt to modify the PET fibre surface by chemical treatment and to see the effects on compressive strength, split tensile strength and flexural strength, of concrete for making PET-reinforced concrete.

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II. MATERIALS AND METHOD

The following materials were used in the present study

Materials Used: Details are presented in table below

Table I Details of material used

Name of the material	Source of the materials
Cement	PSC manufactured by ACC
PET	Recron 3s polyester fibre Manufactured by Reliance Industries
Distilled water	Sai Enterprises, Sindri, Dhanbad
NaOH	Sodium hydroxide pellets purified, E. Merck India Limited
HCl	Ranken HCl, Manufactured by RFCL Limited

General properties of the fibre used in presented in the table II below

Table II Properties of Recron 3s Fibre used

Properties	Units	Polyester
Shape	-----	Triangular
Cut length	Mm	12
Effective diameter	μ(micron)	20-40
Specific gravity	---	1.34-1.39
Melting point	⁰ C	250-265
Elongation	%	20-60
Youngs Modulus	Mpa	>5000
Alkaline stability	-----	Very Good

Methods

Treatment of polyester fibre and addition of fibre

The dispersion of untreated fibre in concrete mix was not uniform. Therefore, the fibres were treated with 2% NaOH (alkaline) solution to see dispersion effect.

Following steps were carried out for the treatment of fibre:-

Preparation of 2% NaOH solution (by weight)- 2% NaOH solution was prepared by dissolving 2gm of NaOH in 20-30ml (approx.) of distilled water and make up the volume of 100 ml.

Fibres were immersed in 2% NaOH solution for 24 hours.

The alkaline treated fibres were subsequently washed 2 to 3 time using distilled water until no alkali was present in the wash.

Then after washed fibre was oven dried at a temperature of 110-120°C for 2-3 hours. FTIR Spectra was obtained in each case.

Polyester fibre (12mm size) was added in concrete at percentages of 0%, 0.20%, 0.25%, and 0.30% by weight of cement. This addition was carried out with both untreated & treated fibre.

Testing of fibre

Fourier Transform Infrared spectrophotometer (FTIR)

The infrared spectra of polyester fibre were recorded in the range of 4000-400 cm⁻¹ on Shimadzu Corpn Japan Instrument, at CIF, BIT Mesra Ranchi

Testing of cement

Portland Slag Cement conforming to IS: 455 was used in the entire experimental study. To avoid the long storage times and to avoid the loss of strength, cement was procured according to the phase wise requirement. The cement was stored

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in bags in air tight room to have minimum exposure to humidity. The detail of physical properties of cement is presented in table III

Table III Physical and mechanical properties of cement

Properties	Results	Standard Limits (IS: 455)
Consistency	32%	-
Soundness	Expansion 4 mm	<10mm
Initial setting time (min)	115 minutes	>30 min
Final setting time	295 minutes	<600 min
Specific gravity	3.123	-
Fineness	1.5% Retain on 90 micron sieve	<10%
Compressive strength	N/mm ²	N/mm ²
1. 3days	17.50	>16
2. 7days	23.30	>22
3. 28 days	34.50	>33

According to table III, the test results are within standard limits.

Testing of aggregate

Aggregates are the important constituents in concrete. The fact that the aggregates occupy 70-80% of volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable. The test results conducted on fine and coarse aggregate for this Research work are given in table IV and V respectively.

Table IV Test results of Fine Aggregate

Test	Fine Aggregate
Zone	III
Moisture content	0.20%
Specific gravity	2.622
Fineness Modulus	2.34
Water Absorption	1.15%

Table V Test results of Coarse Aggregate

Test	Coarse Aggregate
Moisture content	0.2 %
Water absorption	0.55 %
Specific gravity	2.844
Crushing value	23.76 %
Impact value	15.875 %

Proportioning material for M₂₅ grade of concrete mix

M₂₅ grade of concrete has been decided for present work as per IS 10262:2009. The mix proportions are given in Table VI

Table VI Quantity of Materials for M₂₅ Concrete

Water	Cement	fine aggregate	coarse aggregate
202.88 kg/m ³	445.53 kg/m ³	598.20 kg/m ³	1232.61 kg/m ³
0.45	1	1.34	2.77

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Table VII Nomenclature

Concrete mix sample code	Description
F ₀	Addition of 0% fibre by weight of cement
F _{U0.20}	Addition of 0.20% untreated fibre by weight of cement
F _{T0.20}	Addition of 0.20% treated fibre by weight of cement
F _{U0.25}	Addition of 0.25% untreated fibre by weight of cement
F _{T0.25}	Addition of 0.25% treated fibre by weight of cement
F _{U0.30}	Addition of 0.30% untreated fibre by weight of cement
F _{T0.30}	Addition of 0.30% treated fibre by weight of cement

III. RESULTS AND DISCUSSION

FTIR studies of polyester fibre:

The FTIR spectra of PET fibre untreated and PET fibre treated are shown in Figure 1 & 2.

FTIR-PET-Untreated (in Wave number cm⁻¹): 3541, 2962, 2893, 2391, 2113, 1944, 1805, 1712, 1589, 1512, 1396, 1242, 1087, 964, 887, 825, 717

FTIR-PET-Treated (in Wave number cm⁻¹): 3549, 2962, 2893, 2391, 2098, 1951, 1805, 1705, 1512, 1396, 1234, 1095, 1018, 840, 717

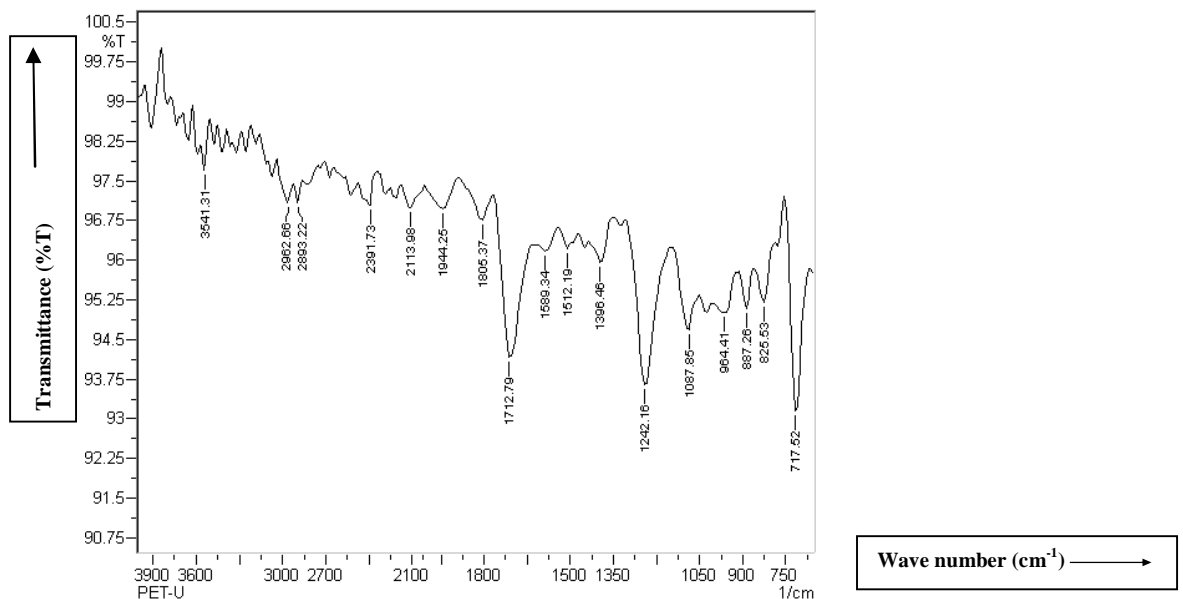


Fig. 1. FTIR spectra Polyethylene terephthalate untreated (PET-U)

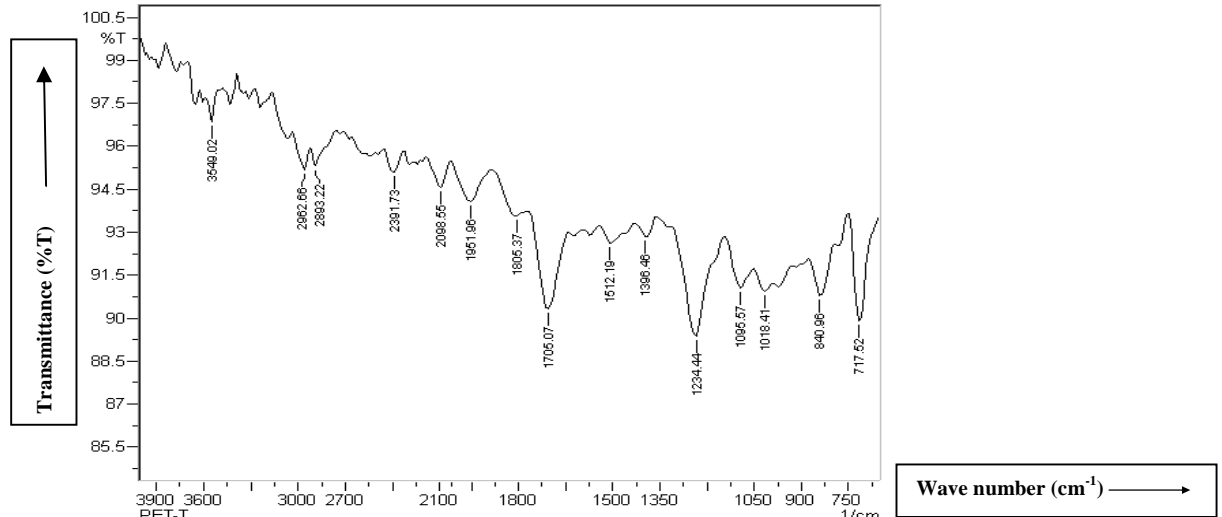


Fig. 2. FTIR spectra Polyethylene terephthalate treated (PET-T)

FTIR spectra of untreated PET fibre and treated PET fibre are shown in Figure 1 and Figure 2. The spectra of the both fibre treated or untreated are almost same, except for some noticeable changes in the range of 1087 cm^{-1} to 825 cm^{-1} . One of the major changes can be noticed in the peak at 1018 cm^{-1} and 840 cm^{-1} . Both the peaks may be assigned to branched chain hydrocarbons and polar (ionic) group. As the NaOH has been used to improve its dispersion in water, the polar group will adhere on the PET surface giving better dispersion of the fibre in water. Better dispersion of the PET fibre in cement-concrete mix will help in increasing the strength of the concrete.

Properties of Fresh Concrete

Each of the concrete mix was tested for its workability. Here slump test has being done to examine the degree of workability. Workability is the basic property of fresh concrete that was assessed in terms of slump value. To check the slump value of fresh concrete, the slump cone test was conducted on all concrete mixes. The slump cone specified by IS: 7320-1974 was used to measure the slump of fresh concrete.

Slump test

The slump value obtained for different percentages of untreated & treated fibre reinforced concrete are given in table VIII & fig. 3.

Table VIII Slump value of fibre reinforced concrete (FRC)

Concrete Mix	Slump (mm)	Variation of slump w.r.t. F_0	Variation of slump value in treated w.r.t untreated FRC
F_0	72	0%	-----
$F_{U.20}$	60	-16.67%	+3.33%
$F_{T.20}$	62	-13.88%	
$F_{U.25}$	55	-23.61%	+3.63%
$F_{T.25}$	57	-20.83%	
$F_{U.30}$	48	-33.33%	+6.25%
$F_{T.30}$	51	-29.16%	

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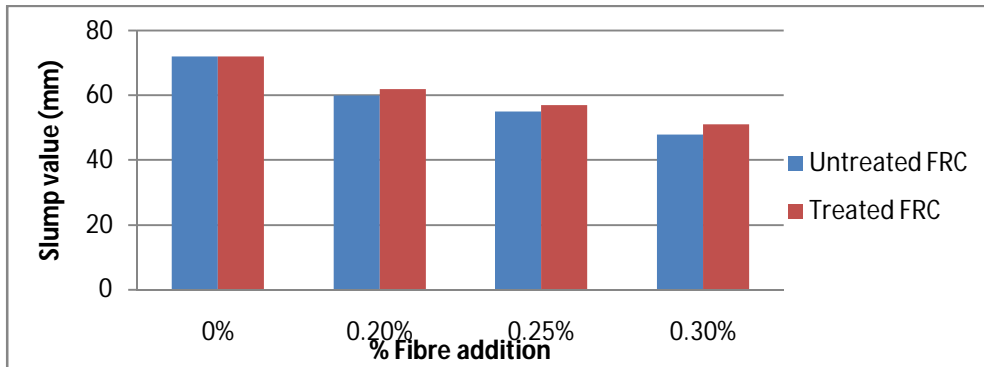


Fig. 3. Slump value of untreated vs treated FRC

From table fig. 3, it has been found that with percentage increase in untreated fibre reinforced concrete, the slump value gradually decreasing. Also, in case of treated fibre reinforced concrete, the slump value gradually decreases with percentage increase in treated fibre. But, while comparing the slump value of untreated & treated fibre reinforced concrete, it was found that the slump value of treated fibre reinforced concrete is slightly more as compared to untreated fibre reinforced concrete at the same percentage addition of fibre.

In this work, the slump range was taken as 50-75 mm and the slump values of different fibre reinforced concrete mix lies approximately between 50 to 75 mm as per desired.

Test results for hardened concrete

The most valuable property of concrete is the compressive strength because it gives the overall quality of hardened concrete. The results for compressive strength test, split tensile test and the flexure strength test have been tabulated below:-

Compressive strength test

The compressive strength test was conducted on 150 mm size of cubes at 7, and 28 days after proper curing process. The compressive strength is determined using 2000 kN compression testing machine in accordance with IS: 516-1959. The values of compressive strength for different percentages of untreated & treated fibre reinforced concrete after 7 and 28 days of proper curing are given in table IX & fig. 4.

Table IX Compressive strength test result for fibre reinforced concrete after 7 and 28 days

Concrete Mix	Avg. compressive strength (N/mm ²) after 7 days	Variation of compressive strength w.r.t. F ₀ after 7 days	Avg. compressive strength (N/mm ²) after 28 days	Variation of compressive strength w.r.t. F ₀ after 28 days
F ₀	23.55	0%	33.89	0%
F _{U.0.20}	24.00	+1.91%	34.78	+2.63%
F _{T.0.20}	25.00	+6.15%	36.55	+7.85%
F _{U.0.25}	25.11	+6.62%	36.22	+6.87%
F _{T.0.25}	26.44	+12.27%	39.33	+16.05%
F _{U.0.30}	24.11	+2.37%	35.89	+5.90%
F _{T.0.30}	26.00	+10.40%	38.22	+12.78%

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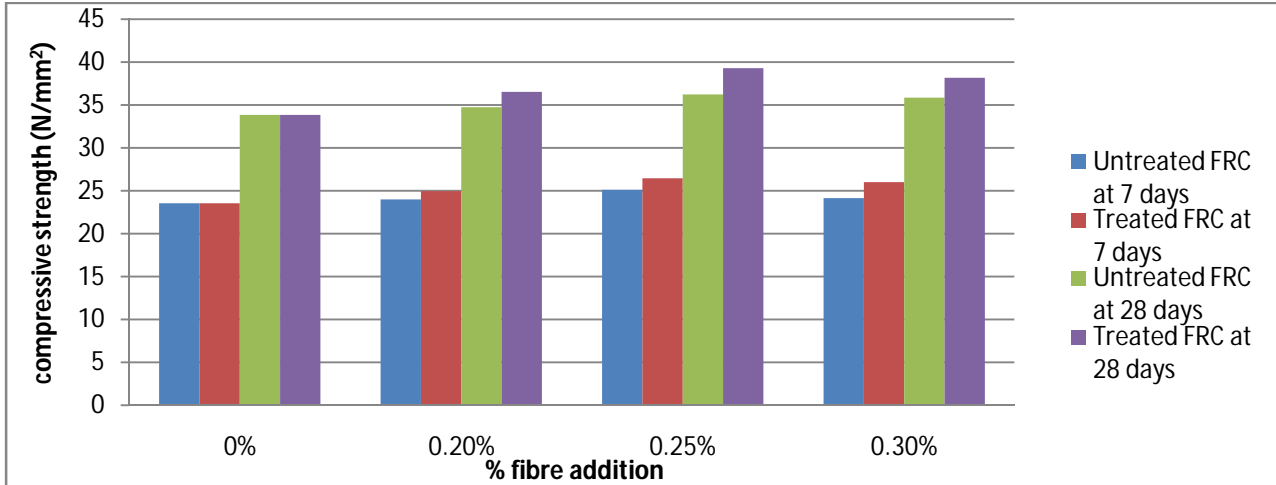


Fig. 4 Compressive strength of untreated vs Treated FRC after 7 & 28 days

From fig. 4, it is observed that among all the percentage fibre addition, the larger strength value was found for 0.25% fibre addition at all the age of curing. The highest strength for treated fibre reinforced concrete with 0.25% addition of treated fibre at 28 days was 39.33 N/mm².

At all percentages of fibre addition in fibre reinforced concrete, the strength of treated fibre reinforced concrete is greater than untreated fibre reinforced concrete.

Split tensile strength test

This test was conducted using 1000 kN compression testing machine as per the procedure given in IS: 5816-1999. The split tensile strength test was conducted on cylindrical specimens of 150 mm diameter x 300 mm height at 7 and 28 days after proper curing process.

The values of split tensile strength for different percentages of untreated & treated fibre reinforced concrete after 7 and 28 days of proper curing are given in table X & fig. 5.

Table X Split tensile test data for fibre reinforced concrete after 7 & 28 days

Concrete Mix	Avg. Split tensile strength (N/mm ²) after 7 days	Variation of split tensile strength w.r.t. F ₀ after 7 days	Avg. Split tensile strength (N/mm ²) after 28 days	Variation of split tensile strength w.r.t. F ₀ after 28 days
F ₀	1.62	+0%	2.26	+0%
F _{U0.20}	1.91	+17.9%	2.68	+18.58%
F _{T0.20}	1.98	+22.22%	2.82	+24.78%
F _{U0.25}	2.26	+39.50%	3.14	+38.93%
F _{T0.25}	2.41	+48.76%	3.39	+50.00%
F _{U0.30}	2.12	+30.86%	3.04	+34.51%
F _{T0.30}	2.26	+39.50%	3.25	+43.80%

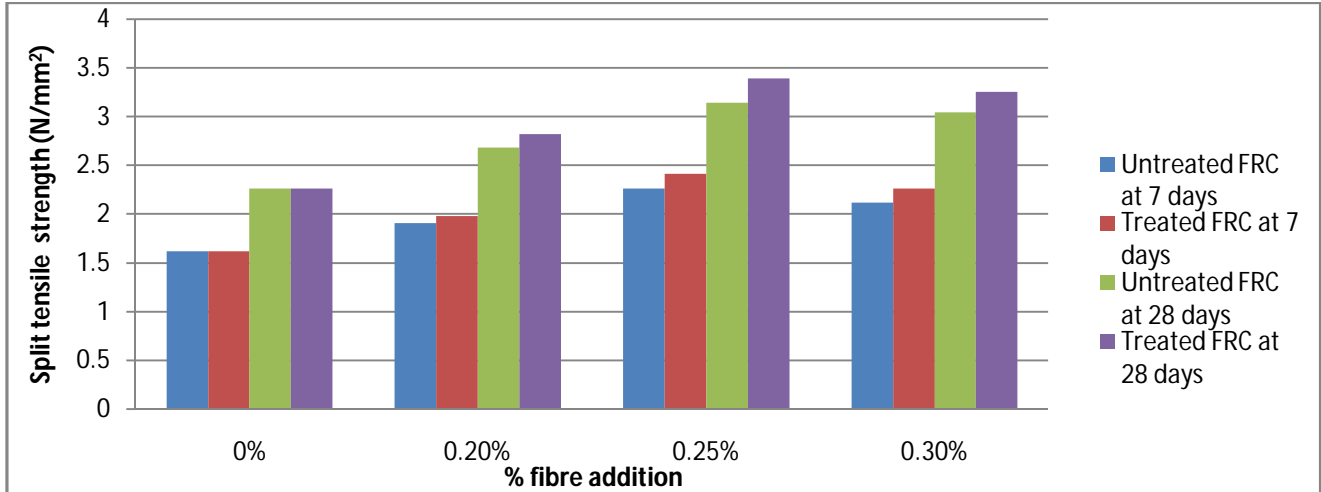


Fig. 5 Split tensile strength of untreated vs Treated FRC after 7 & 28 days

From fig. 5, it is observed that among all the percentage fibre addition, the larger split tensile strength value was found for 0.25% fibre addition at all the age of curing. The highest split tensile strength for treated fibre reinforced concrete with 0.25% addition of treated fibre at 28 days was 3.39 N/mm².

At all percentages of fibre addition in fibre reinforced concrete, the split tensile strength of treated fibre reinforced concrete is greater than untreated fibre reinforced concrete.

Flexural Strength Test

The flexural strength test was performed in accordance with IS: 516-1959 on the beams of size 500 x 100 x 100 mm after curing period of 7 and 28 days with 200 kN universal testing machine. The specimen was supported on two roller support spaced at 400 mm center to center.

The values of flexural strength for different percentages of untreated & treated fibre reinforced concrete after 7 and 28 days of proper curing are given in table XI & fig. 6.

Table XI Flexural strength test data for fibre reinforced concrete after 7 & 28 days

Concrete Mix	Avg. Flexural strength (N/mm ²) after 7 days	Variation of flexural strength w.r.t. F ₀ after 7 days	Avg. Flexural strength (N/mm ²) after 28 days	Variation of flexural strength w.r.t. F ₀ after 28 days
F ₀	2.40	+0%	3.40	+0%
F _{U0.20}	2.60	+8.33%	3.60	+5.88%
F _{T0.20}	2.80	+16.66%	3.80	+11.76%
F _{U0.25}	3.00	+25.00%	4.20	+23.52%
F _{T0.25}	3.20	+33.33%	4.40	+29.41%
F _{U0.30}	2.80	+16.66%	4.00	+17.65%
F _{T0.30}	3.00	+25.00%	4.20	+23.52%

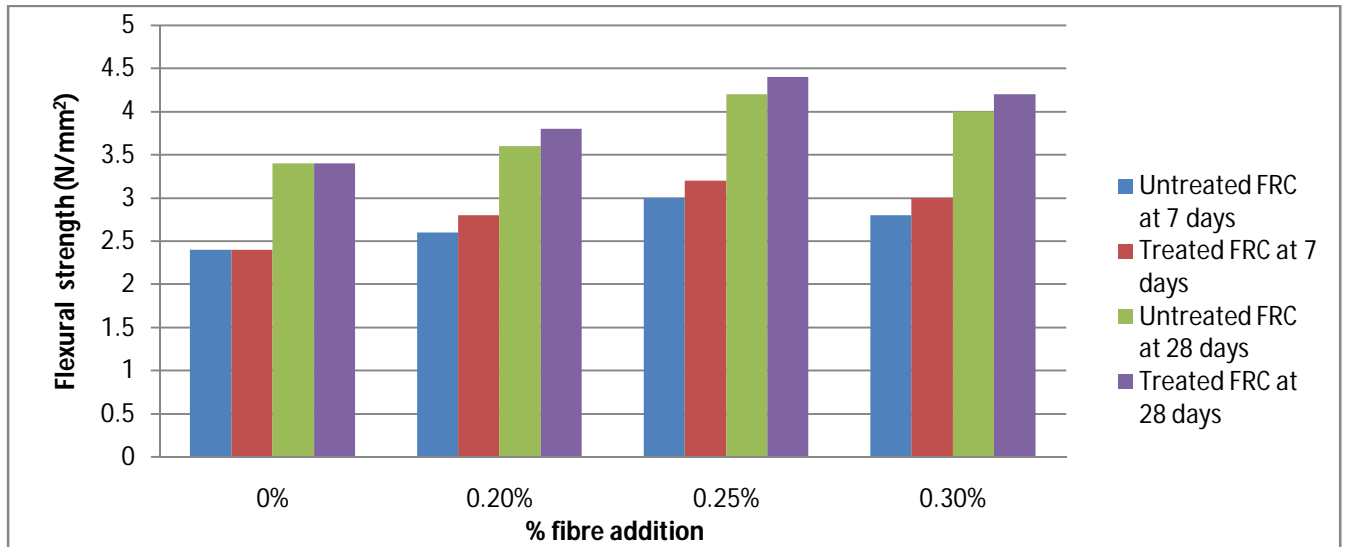


Fig. 6 Flexural strength of Untreated vs Treated FRC after 7 & 28 days

From fig. 6, it is observed that among all the percentage fibre addition, the larger flexural strength value was found for 0.25% fibre addition at all the age of curing. The highest flexural strength for treated fibre reinforced concrete with 0.25% addition of treated fibre at 28 days was 4.40 N/mm².

At all percentages of fibre addition in fibre reinforced concrete, the flexural strength of treated fibre reinforced concrete is greater than untreated fibre reinforced concrete.

IV. CONCLUSIONS

PET fibre has multi fold applications. It has been also used in fibre reinforced concrete. However, the hydrophobic nature of PET fibre results in poor wettability with cement, sand and other common concrete admixture. Proper bonding between the hydrophobic PET fibre and hydrophilic cement matrix is only possible with surface modification. In the present work attempt was made to modify the PET fibre by sodium hydroxide treatment at ambient temperature. The chemical sodium hydroxide selected was such that it could be readily used in the cement admixture without adversely affecting the properties of the concrete. The dosage and the effect of sodium hydroxide on the properties, especially flexural and compressive strength, of concrete were studied. It may conclude that-

- The addition of untreated and treated fibre (0.25% by weight of cement) into the concrete improved its compressive strength by 6.87% and 16.05% respectively after 28 days of curing.
- Due to the addition of untreated and treated fibre (0.25% by weight of cement) in the concrete, its split tensile strength increased by 38.93% and 50% respectively after 28 days of curing.
- The flexural strength of concrete improved by 23.52% and 29.41% for untreated and treated fibre reinforced concrete (0.25% by weight of cement) respectively after 28 days of curing.
- The workability of treated fibre reinforced concrete was found to be more as compared to untreated fibre reinforced concrete.
- The optimum percentage of polyester fibre that can be used to reinforce concrete is 0.25% by weight of cement.

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