An Experimental Investigation of Mechanical Properties of Chemically Treated Polyester Fibre Reinforced Concrete

Anjuli Singhai
PG Student
Department of Civil Engineering
IMEC Sager (M.P) India - 470001

Mr. Rahul Satbhiya
Associate Professor & Head of Department
Department of Civil Engineering
IMEC Sager (M.P) India - 470001

Dr. D. Rai
Director
IMEC Sager (M.P) India - 470001

Dr. Shishir Jain
Principal
IMEC Sager (M.P) India - 470001

Abstract

Polyethylene terephthalate (PET) fibers have been used in fiber reinforced concrete, but poor dispensability of PET, due to low wettability, cause reduce strength of the fiber 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 fiber. In present work attempt to modify the PET fiber surface by chemical treatment at ambient temperature and see the effects on compressive strength, split tensile strength and flexural strength. A comparison will be drawn between all these materials. In this project treated polyester fiber was used to prepare fiber reinforced concrete. The polyester fiber was used at different percentages (0%, 0.20%, 0.25%, & 0.30%) by weight of cement and comparison of strength of concrete for treated fiber reinforced concrete at different percentage was carried out. The concrete samples were prepared (cube, cylinder & beam) and cured in normal water for 7, 28 and 56 days. The study was carried out to see the effect of acidic rain on fiber reinforced concrete. Acidic water was prepared by using the concentrated HCl in deionized water respectively. To see the environmental effect, the Concrete samples were cured in acidic for 56 days. The samples were tested for compressive strength, split tensile strength and flexural strength and found that 0.25% of PET fiber by weight of cement may be recommended for optimum dose. The studies indicate that the dispersion of treated fiber in concrete was better with respect to normal fiber. The fiber reinforced concrete was also more resistance against acidic environment with respect to normal concrete. In all aspects, the treated fibre reinforced concrete was found better than normal reinforced concrete.
Keywords: Polyethylene Terephthalate (PET), Fiber Reinforced Concrete, HCL, Strength

---

I. Introduction

The concept of using fibre as reinforcement is not new. From ancient time fibres have been used as reinforcement. Historically, horsehair was used in mortar and straw in mud bricks. In the 1900s, asbestos fibres were used in concrete. In 1911 Porter found that fibre could be used in concrete. Nylon, the first synthetic fibre, was developed by Wallace Carothers, an American researcher at the chemical firm DuPont in the 1930s. The first polyester fibre was introduced by John Rex Winfield and James Tennant Dickson, British chemists working at the Calico Printers' Association, in 1941

There are many different types of fibres that can be used to reinforce polymer matrix composites are: glass fibre, natural fibres, asbestos fibre, carbon, aramid, ultra-high molecular weight polyethylene, polypropylene, polyester and nylon. The change in properties of these fibres is due to the raw materials and the temperature at which the fibre is formed.

The polyester fibre was selected for this research work due to its special characteristics such as strong, resistant to most chemicals, wrinkle resistant, abrasion resistant, and resistant to stretching and shrinking. The polyester fibre has been tried in polymer reinforced concrete due to its low cost, good mechanical properties, size and shape for suitability. Polymer improves toughness, resistance to impact and durability of reinforced concrete.

Recron 3s polyester Fibres are engineered micro fibres with a unique “triangular” cross-section, used as secondary reinforcement as it holds the concrete together after it cracks. The importance of Polyester Fibres as secondary reinforcement in concrete is that it improves the strength, durability, and toughness and fatigue resistance. The interaction between the fibre and concrete matrix is the fundamental property that affects the performance of a cement based fibre composite materials. An understanding of this interaction is essential for forecasting the fibre contribution and for predicting the behaviour of such composites.

II. LITRETURE REVIEW

M.Haghighatkishet. al. (1992) studied the structural effects on polyester fibre due to its alkaline hydrolysis. Partially oriented and fully drawn poly (ethylene terephthalate) (PET) fibres were treated with aqueous solution of 10% sodium hydroxide at 30°C. The weight loss density, diameters and birefringence of fibres were measured. X-ray diffract on studies were carried out and SEM photomicrographs of fibres were obtained. Both yarn types showed progressive weight loss and reduction of diameters with increasing time of alkaline treatment. There were no changes in orientation and crystallinity of fibres. Surface morphology differed between partially oriented and fully drawn fibres. It is concluded that the reaction occurs preferentially in the region of low structural order on the surface of fibres.

Bing Chen et. al. (2005) investigated the mechanical properties of polymer-modified concretes containing expanded polystyrene beads. Styrene-butadiene rubber (SBR) latex as a polymeric admixture was applied in lightweight expanded polystyrene (EPS) concrete

Prof. Indrajit Patel et. al. (2010) studied the properties of concrete after inclusion of recron3s fibre. The findings were that the compressive strength gaining is comparatively slower at 3 and 7 days for all mix particularly for high 60% of flyash and highermix M35and M40. Targeted values at 7 days for plain HVFA concrete is of the 72% to 78% which is as better as normal concrete without flyash. Beyond 7 days the increase in strength is of order 65 to 76% and all mix shows satisfactory values at age of 28 days. Inclusion of fibre at the rate of 0.25% by mass of the cementitious material does not have much effect on the w/c ration and slump values as well.

III. OBJECT

The present work is aimed to investigate the effect of treatment of polyethylene terephthalate (PET) fibre with NaOH on the strength of concrete.

- To know the optimum dosage of treated polyester fibre in concrete.
- Selection of mix design for M25 grade of concrete mix.
- To study the properties of harden concrete (compressive strength, split tensile strength and flexural strength).
- To study the environmental effect (acidic environment) on the characteristic strength of Fibre reinforced concrete.

IV. MATERIAL & METHODS

Table – 1
Material Used

S. no.	*Name of the material*	*Source of the materials*
1	*Cement*	*PSC manufactured by ACC*
2	*Fine aggregate*	*Local from Bilaspur*
3	*Coarse aggregate*	*Local from Bilaspur*
4	*Polyester Fiber*	*Shree Yamuna Ji enterprises Bilaspur*
5	*NaOH*	*Saraswati enterprises DayalbandBilaspur*
6	*HCL*	*Saraswati enterprises DayalbandBilaspur*
7	*Distilled Water*	*Filter Wala CMD ChowkBilaspur*
8	*Water*	*Tap water*

A. Treatment of Polyester Fibre & Addition of Fibre

Normal or untreated fibre was not able to disperse uniformly in concrete. So, the fibres were treated with 1.8% NaOH (alkaline) solution to see dispersion effect.

1) For the Treatment of Fiber the Following Steps Were Taken

- Preparation of 1.8% NaOH solution (by weight): 1.8% NaOH solution was prepared by dissolving 1.8gm of NaOH in 20-30ml of distilled water and make up the volume of 100 ml.
- Fibers were immersed in 1.8% NaOH solution for 24 hours.
- Then after washed the alkaline treated fiber subsequently 2 to 3 times using distilled water until no alkaline was present in the wash.
- Then the fiber was oven dried at a temperature of 110-120ºC for 2-3 hours after the wash. We observe that FTIR Spectra was obtained in each case.

Polyester fibre (12mm length) 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 treated fibre.

2) Physical & Mechanical Properties of Cement

Table – 2

Properties	*Results*	*Standard Limits (IS: 455)*
Consistency	*30%*	_
Soundness	*Expansion 3mm*	*<10mm*

Initial setting time (min)	*110 minutes*	*>30 min*
Final setting time	*280 minutes*	*<600 min*
Specific gravity	*3.20*	*_*
Fineness	*3% Retain on 90 micron sieve*	*<10%*
Compressive strength	*N/mm^2*	*N/mm^2*
1. 3days	*18.10*	*>16*
2. 7days	*22.30*	*>22*
3. 28 days	*33.50*	*>33*

3) *Properties of Fine Aggregate*

Table – 3

S. No.	Test	Fine Aggregate
1	Zone	III
2	Moisture content	0.21%
3	Specific gravity	2.638%
4	Fineness Modulus	2.31%
5	Water Absorption	1.18%

4) *Properties of Coarse Aggregate*

Table – 4

S. No.	Test	Coarse Aggregate
1	Moisture content	0.2%
2	Water absorption	0.60%
3	Specific gravity	2.854%
4	Crushing value	23.86%
5	Impact value	15.89%

5) *Mix Proportion of Concrete*

Table – 5

	Design	w/c ratio	Mix	Slump	Compressive strength (N/mm^2)	
S. No.	Mix		proportion	(mm)	7 days	28 days
1	M_1	0.44	1:1.38:2.77	77	21.43	29.74
2	M_2	0.46	1:1.40:2.95	70	24.10	34.37

Table – 6

Concrete Mix	Slump(mm)	Variation of slump w.r.t. F_0
F_0	70	0%
$F_{0.20}$	60	-14.28%
$F_{0.25}$	56	-20%
$F_{0.30}$	50	-27.14%

6) *Slump Value of Fibre Reinforced Concrete*

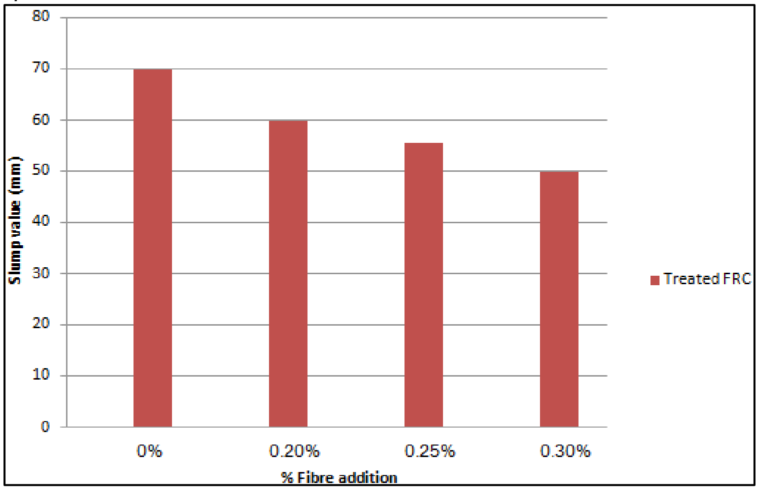

Fig. 1:

B. *Compressive Strength Test Data for Fibre Reinforced Concrete after 7days*

Table – 7

Concrete Mix	Sample	Failure load (kN)	Compressive strength (N/mm^2)	Avg. Compressive Strength (N/mm^2)	Variation of compressive Strength w.r.t F_0
F_0	1	518	23.02	23.46	0%
	2	538	23.91		

$F_{0.20}$	1	552	24.53	24.86	+5.96%
	2	567	25.20		
$F_{0.25}$	1	600	26.07	26.22	+11.76
	2	580	25.77		
$F_{0.30}$	1	578	25.68	25.90	+10.40%
	2	588	26.13		

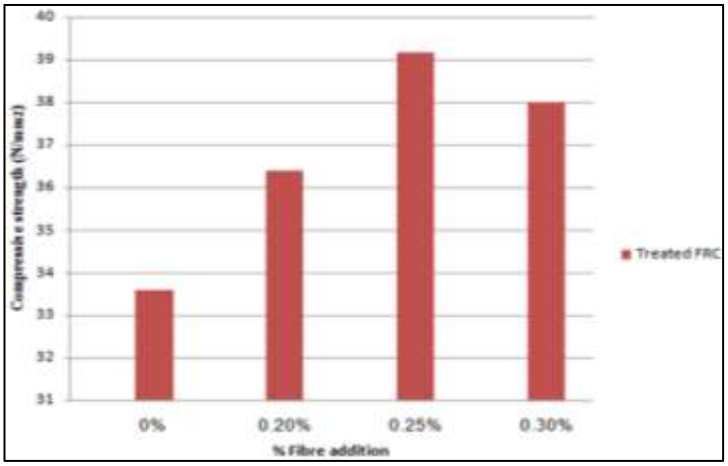

Fig. 2:

C. Compressive Strength Test Data for Fibre Reinforced Concrete after 28 Days

Table – 8

Concrete Mix	Sample	Failure load (kN)	Compressive strength (N/mm^2)	Avg. Compressive Strength (N/mm^2)	Variation of compressive Strength w.r.t F_0
F_0	1	753	33.46	33.79	0%
	2	768	34.13		
$F_{0.20}$	1	825	36.66	36.33	+7.51%
	2	810	36.00		
$F_{0.25}$	1	916	40.70	39.15	+15.86
	2	846	37.60		
$F_{0.30}$	1	850	37.77	37.99	+12.42%
	2	860	38.22		

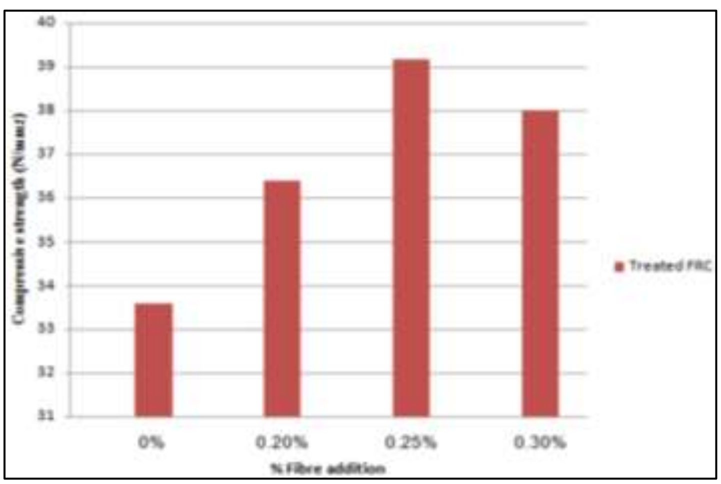

Fig. 3:

D. Compressive Strength Test Data for Fibre Reinforced Concrete after 56 Days Normal Water Curing

Table – 9

Concrete Mix	Sample	Failure load (kN)	Compressive strength (N/mm^2)	Avg. Compressive Strength (N/mm^2)	Variation of compressive Strength w.r.t F_0
F_0	1	814	36.17	36.52	0%

	2	830	36.88		
$F_{0.20}$	1	905	40.22	39.82	+9.03%
	2	887	39.42		
$F_{0.25}$	1	1002	44.53	44.08	+20.70%
	2	982	43.64		
$F_{0.30}$	1	943	41.91	42.31	+15.85%
	2	961	42.71		

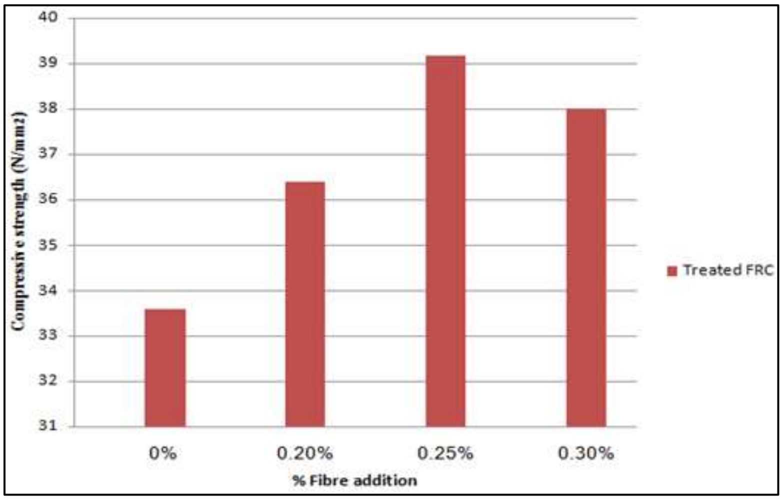

Fig. 4:

E. Compressive Strength Test Data for Fibre Reinforced Concrete after 56 Days Acidic

1) Curing

Table – 10

Concrete Mix	Sample	Failure load (kN)	Compressive strength (N/mm^2)	Avg. Compressive Strength (N/mm^2)	Variation of compressive Strength w.r.t F_0
F_0	1	770	34.22	34.55	0%
	2	785	34.88		
$F_{0.20}$	1	875	38.88	38.44	+11.25%
	2	855	38.00		
$F_{0.25}$	1	955	42.44	42.99	+24.42
	2	980	43.55		
$F_{0.30}$	1	915	40.66	41.10	+18.95%
	2	935	41.55		

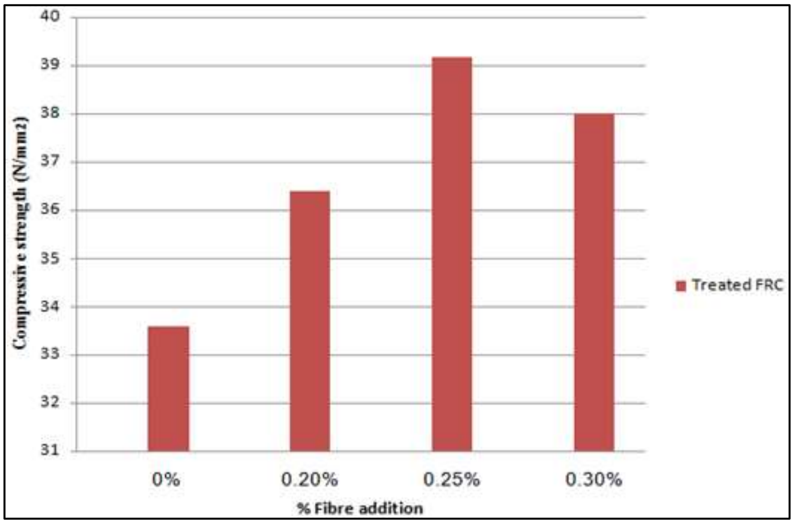

Fig. 5:

F. Flexural Strength Test Data for Fibre Reinforced Concrete after 7 Days

Table – 11

Concrete Mix	Size of beam (mm x mm x mm)	Span (mm)	Failure load (KN)	Flexural strength(N/mm²)= Pl/bd²	Variation of flexural strength w.r.t F_0
F_0	500 x 100 x 100	400	5.50	2.20	0%
$F_{0.20}$	500 x 100 x 100	400	6.50	2.60	+16.66%
$F_{0.25}$	500 x 100 x 100	400	7.50	3.00	+36.36%
$F_{0.30}$	500 x 100 x 100	400	7.00	2.8	+27.27%

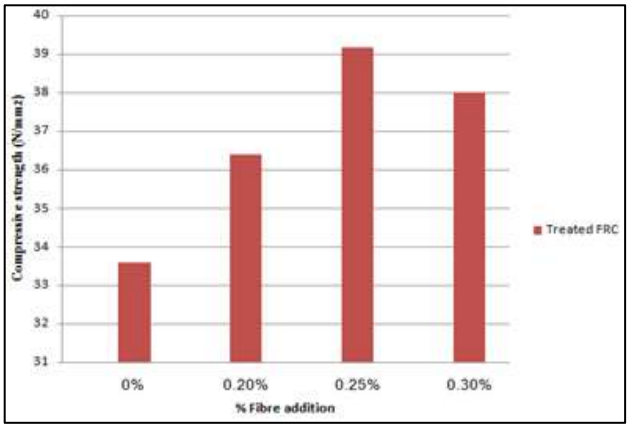

Fig. 6:

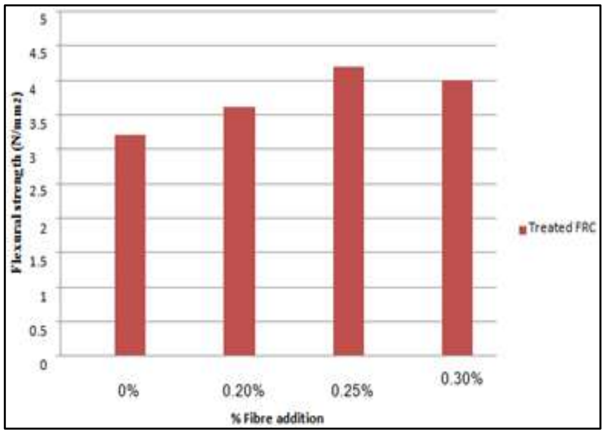

Fig. 7:

G. Flexural Strength Test Data for Fibre Reinforced Concrete after 28 Days

Table – 12

Concrete Mix	Size of beam (mm x mm x mm)	Span (mm)	Failure load(KN)	Flexural strength(N/mm²)= Pl/bd²	Variation of flexural strength w.r.t F_0
F_0	500 x 100 x 100	400	8.00	3.20	0%
$F_{0.20}$	500 x 100 x 100	400	9.00	3.60	+12.5%
$F_{0.25}$	500 x 100 x 100	400	10.50	4.20	+31.25%
$F_{0.30}$	500 x 100 x 100	400	10.00	4	+25.00%

H. Flexural Strength Test Data for Fibre Reinforced Concrete after 56 Days Acidic Curing

Table – 13

Concrete Mix	Size of beam (mm x mm x mm)	Span(mm)	Failure load (kN)	Flexural strength(N/mm²)=PL/bd²	Variation of Flexural strength w.r.t F_0
F_0	500 X100 X 100	400	9.00	3.60	0%
$F_{0.20}$	500 X100 X 100	400	11.00	4.40	22.22%
$F_{0.25}$	500 X100 X 100	400	13.00	5.20	44.44%
$F_{0.30}$	500 X100 X 100	400	12.50	5.00	38.89%

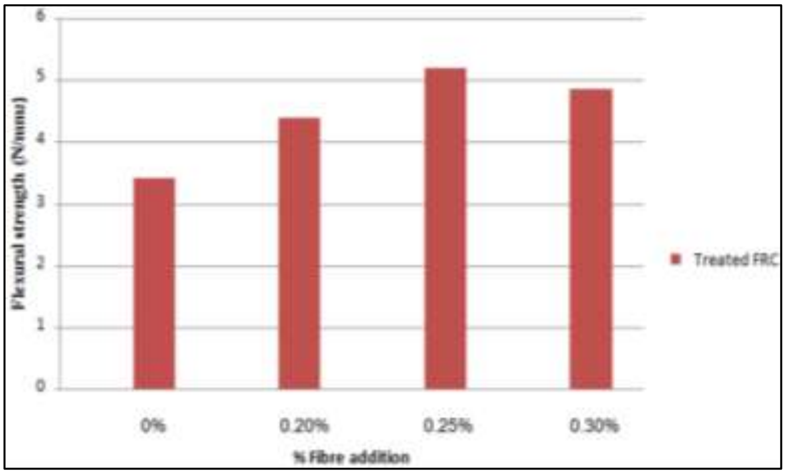

Fig. 8:

I. *Compressive Strength Test Result for Fibre Reinforced Concrete after 7, 28 & 56 Days in Normal Water Curing (NWC)*

Table – 14

Concrete Mix	*Avg. Comp. Strength (N/mm^2) After 7 days*	*%age Variation of comp.st. w.r.t. F_0 After 7 days*	*Avg. Comp. Strength (N/mm^2) After 28 days*	*%age Variation of comp.st. w.r.t. F_0 After 28 days*	*Avg. Comp. Strength (N/mm^2) After 56 days*	*%age Variation of comp.st. w.r.t. F_0 After 56 days*
F_0	23.46	0%	33.79	0%	36.52	0%
$F_{0.20}$	24.86	+5.96%	36.33	+7.51%	39.32	+9.03%
$F_{0.25}$	26.22	+11.76%	39.15	+15.86%	44.08	+20.70%
$F_{0.30}$	25.90	+10.40%	37.99	+12.42%	42.31	+15.85%

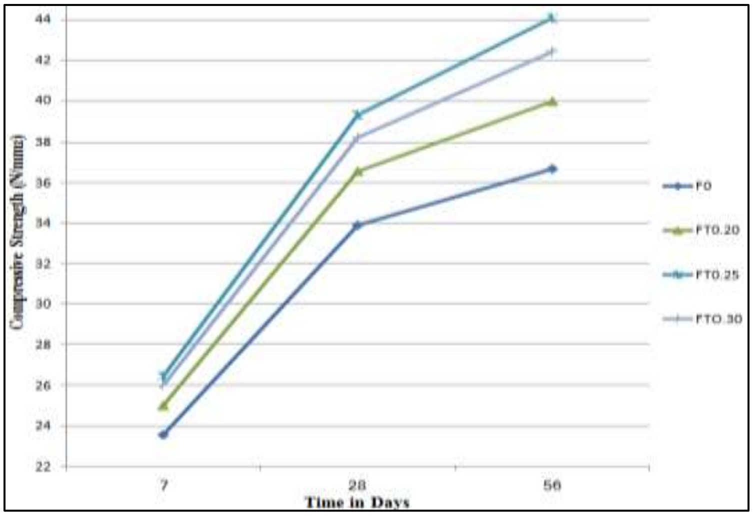

Fig. 9:

J. *Flexural Strength of Treated Fibre Reinforced Concrete after 7, 28 & 56 Days in Normal Water Curing (NWC)*

Table – 15

Concrete Mix	*Avg. Flexural Strength (N/mm^2) After 7 days*	*% age Variation of Flexural.st. w.r.t. F_0 After 7 days*	*Avg. Flexural Strength (N/mm^2) After 28 days*	*% age Variation of strength w.r.t. F_0 After 28 days*	*Avg. flexural Strength (N/mm^2) After 56 days*	*% age Variation of strength w.r.t. F_0 After 56 days*
F_0	2.2	0%	3.20	0%	3.80	0%
$F_{0.20}$	2.60	+18.88%	3.60	+12.5%	4.60	21.05%
$F_{0.25}$	3.0	+36..36%	4.20	+31.25%	5.30	39.47%
$F_{0.30}$	2.8	+27.27%	4	+25.00%	5.10	34.21%

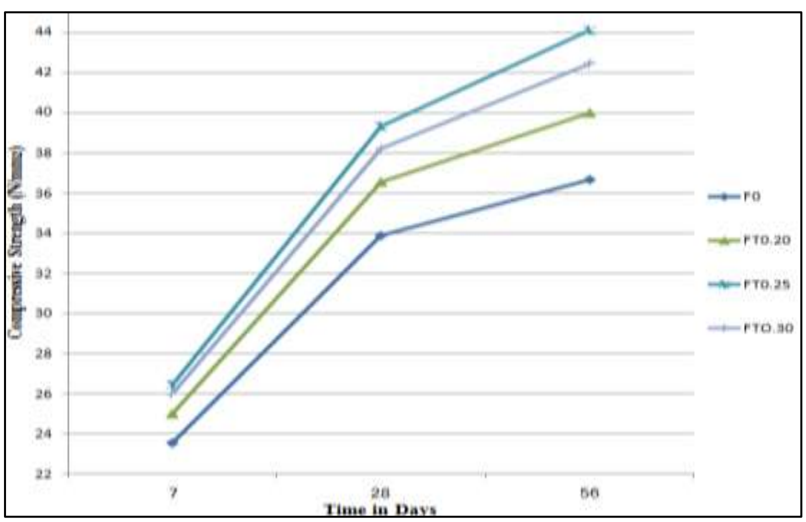

Fig. 10:

K. Flexural Strength Test Data for FRC after 56 Days of Normal Water Curing (NWC) & Acidic Curing

Table – 16

Concrete Mix	*Avg Flexural Strength (N/mm^2) After 56 days NWC*	*Variation of Flexural strength w.r.t. F_0 After 56 days NWC*	*Avg Flexural Strength (N/mm^2) After 56 days AC*	*Variation of Flexural strength w.r.t. F_0 After 56 days AC*	*Variation of Flexural Strength of FRC in AC w.r.t NWC*
F_0	3.80	0%	3.50	0%	-5.70
$F_{0.20}$	4.60	+21.05%	4.30	+22.85%	-3.59
$F_{0.25}$	5.30	+39.47%	5.10	+45.71%	-2.47
$F_{0.30}$	5.10	+34.21%	4.90	+40.00%	-2.94

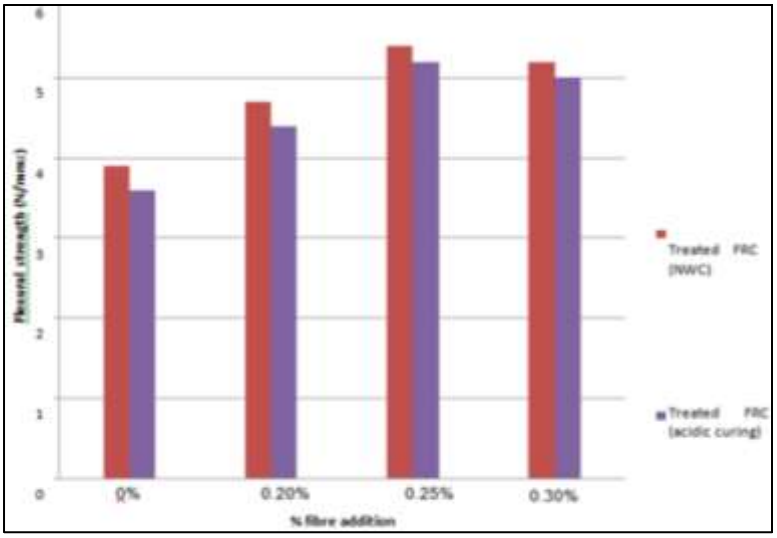

Fig. 11:

V. CONCLUSION

- The compressive strength, & flexural strength of PET fiber reinforced concrete increases with increase in percentage PET (treated) up to 0.25% fiber by weight of cement and then decrease with increase in percentage fiber.
  a) The compressive strength and flexural strength of treated FRC increased by 16.05%, 50% and 29.41% respectively with respect to 0% addition of fiber, after 28 days of normal water curing.
  b) The compressive strength and flexural strength of treated FRC increase 20.32%, 53.62% and 38.46% respectively after 56 days of normal water curing.
- The workability of treated fiber reinforced concrete was found to be Greater.
- In all cases in this study the treated FRC was found better than normal reinforced concrete.
- With this study, it may be recommend to use 0.25% by weight of cement treated PET FRC for better results.
- The acidic environment affects the durability concrete for all cases but rate of deterioration is less in case of treated PET fiber reinforced concrete and for the optimal % of 0.25 by weight of cement, the deterioration of compressive strength, split tensile strength & flexural strength is 2.03%, 3.30% & 3.70% respectively, with respect to normal water curing of same sample.
- The alkaline environment do also affect the durability but rate of deterioration is less compare to acidic environment. The % decrease of compressive strength by 1.08% after 56 days compared with same sample cured in normal water condition.

REFERENCES

[1] https://en.wikipedia.org/wiki/Fiber-reinforced_concrete
[2] http://theconstructor.org/concrete/fibre-reinforced-polymer/1583/
[3] http://www.elastoplastic.com/index.php/the-history-of-fibre-reinforcement
[4] "World of Chemistry". Thomson Gale. 2005. Retrieved 1 November 2009.
[5] Allen, P (1967). "Obituary". Chemistry in Britain. |first2= missing |last2= in Authors list (help)
[6] Frank Greenaway, 'Whinfield, John Rex (1901–1966)', rev. Oxford Dictionary of National Biography, Oxford
[7] http://textilelearner.blogspot.in/2011/07/polyester-fiber-characteristics-of_11.html
[8] http://www.indiancementreview.com/News.aspx?nId=GPRJhjHn28WpC0foLLK8Rg==
[9] http://www.abcpolymerindustries.com/polymer-news/news/19/q:-what-is-the-difference-between-a-structural-concrete-slab-and-a-plain-concrete-structural-slab
[10] http://www.whatispolyester.com/
[11] http://www.fiberreinforced.org/pages/applications.aspx

[12] M.Haghighatkish and M.Yousefi, "Alkaline Hydrolysis of polyester Fibers-Structural Effects", Iranian Journal of Polymer science & Technology, vol 1, No. 2, pp. 56-61, 1992.
[13] Bing Chen a & Juanyu Liu, "Mechanical properties of polymer-modified concretes containing expanded polystyrene beads", Construction and Building Materials, ELSEVIER, August 2005.
[14] Anita singh and MadhoolikaAgrawal, "Acid rain and its ecological consequences", Journal of Environmental Biology, January 2008, 29(1) 15-24 (2008).
[15] Prof.Indrajitpatel and Dr.C D Modhera, "STUDY BASIC PROPERTIES OF FIBER REINFORCED HIGH VOLUME FLY ASH CONCRETE" Journal of Engineering Research and studies, vol I, issue me, pp 60-70, 2010.
[16] SwarnaNatarajan and J Jeyakodi Moses, "Surface modification of polyester fabric using polyvinyl alcohol in alkaline medium", Indian Journal of Fibre& Textile Research, vol. 37, September 2012, pp. 287-291.
[17] E. Arunakanthi, H. SudarsanaRao and I.V. Ramana Reddy, "EFFECTS OF HYDROCHLORIC ACID IN MIXING AND CURING WATER ON STRENGTH OF HIGH-PERFORMANCE METAKAOLINCONCRETE", International Journal of Applied Engineering and Technology, vol. 2(2), 2012, pp. 68-76.
[18] Irene S. Fahim, Salah M. Elhaggar, HatemElayat, "Experimental Investigation of Natural Fiber Reinforced Polymers", Material Sciences and Applications, 2012, 3, 59-66.
[19] Y.A El-Shekeil, S.M. Sapuan, A. Khalina, E.S. Zaninudin and O.M. Al-Shuja, "Influence of Chemical treatment on the tensile properties of kenaf fiber reinforced thermoplastic polyurethane composite", eXPRESS Polymer Letters, vol.6, No.12 (2012) 1032-1040.