International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 3, Issue 2, pp: (85-94), Month: October 2015 - March 2016, Available at: www.researchpublish.com

Performance Evaluation of Pet-Polyproplene Hybrid Fiber Reinforced Concrete In Terms of Work ability, Strength and Cost Effectiveness

Gurpreet Singh[1], Dr. Sanjay Goel[2]

[1] Student of M.Tech Structure (Part-time) at D.A.V Institute of engineering and technology, Jalandher, Punjab and Working as Assistant professor in department of civil engineering at Lyallpur Khalsa college of engineering, Jalandher, Punjab, India

[2] Working as Assistant professor in the department of civil engineering, D.A.V Institute of engineering and technology, Jalandher, Punjab, India

***Abstract*: PET bottles are major source of plastic waste which may cause different problems related to its disposal, dumping and recycling. PET being a mechanically strong and durable material, provides an opportunity for concrete technologists and researchers to study the use of PET as fibers in concrete, Thus the present experimental investigation was designed to study the effect of replacing Polypropylene fibers with PET fibers in concrete, by hybridization of the two fibers. In this investigation the performance of concrete with PET-Polypropylene fibers is evaluated. The performance of concrete is evaluated in terms of its workability and strength. Workability is measured with Slump cone test and Compaction factor test while the strength of different concrete mixes is measured as Compressive strength, Split tensile strength and Flexural strength etc. Six different types of mixes are prepared using different volume proportions of PET & Polypropylene in concrete. The addition of PET fibers reduced the workability of concrete but this reduction was smaller as compared to the addition of polypropylene fibers. Thus results for compressive, split, and flexural strength shows an improvement for mixes with more proportion of PET fibers & lesser polypropylene fibers. The cost analysis of concrete mixes with reference to the strength gain has shown that the PET-PP hybridization with 0.75% PET and 0.25% PP was the optimum mix proportions of these two fibers considering the cost/strength and overall strength gain among the hybrid fiber reinforced concrete mixes.**

***Keywords*: Workability, Compressive strength, Split tensile strength, flexural strength, Cost effectiveness.**

1. INTRODUCTION

Concrete is widely used as a construction material in civil engineering works for decades. It can be mould in any shape and size without any difficulty. The properties of concrete can be changed by adding some special natural or artificial materials. Some properties of concrete gives good results and some properties have average or poor results. To improve the properties, the concrete is prepared with mixing some additional materials like fibers of different types, admixtures etc. Different types like steel fibers, polypropylene and nylon fibers, asbestos fibers, glass fiber, carbon fiber etc, are made in industries under controlled conditions and supplied to the concrete industries. With the use of these industries made fibers the cost of concrete increases. To reduce the cost of concrete engineers & researchers now focus on utilization of industries waste materials in concrete manufacturing. Plastics are world widely used in form of PET bottles (Polyethylene Terephthalate). PET bottles are used to packing edible oils, jams and sauces, butter, syrups drinking water etc. Major application area of PET bottles is carbonated soft drinks, Mineral water packing, Wine, Liquor and spirit packing etc. Engineers & researchers has observed that, these plastic wastes has good chemical resistance, durability, lightweight, and thus suggested the use of these PET bottles for concrete manufacturing in the form of fibers of different length and sizes.

Concrete has already been incorporated with plastic fibers in the form of polypropylene fibers. In the present study PET waste is used to replace polypropylene fibers in a concrete mix in different proportions to investigate its effects on the performance of the concrete. The performance is evaluated in term of effect on workability, strength, and economy of PET-Polypropylene hybrid fiber reinforced concrete.

II. MATERIAL AND METHODS

Cement: - 43 grade OPC cement used in this study confirming to BIS 8112-1989.

Coarse aggregates: -Locally available Crushed stones size between all in one ≤ 20 mm is used.

Fine aggregates: - Local available river silver sand used in this experimental works.

Fibers: - Two types of fibers were used in experimental works:-

1) Waste plastic bottles fibers (PET) prepared with cutting of waste plastic bottles. It is converted in to pallets of 19 mm long and 3 mm wide in dimensions. The whole material prepared manually with scissors.

2) ECONO-NET Polypropylene fibers monofilaments by FORTA are used in this experimental works with dimensions 19 mm long.

Water: - Portable drinking water is used for mixing of concrete.

The material testing is done in laboratory as per recommendation of IS Code -383-1970, IS Code-8112-1989, IS Code 2386 (part 1-8) etc.

Six different M35 grade concrete mixes were prepared for this experimental study. Polypropylene fibers (PP) and PET fibers were added to the control mix designed, with different percentage of PET and PP fibers by total volume of concrete. The total volume fraction of fiber was kept at 1%. The detail of mixes is given in table 01 below:-

TABLE 1: Concrete Mixes designation

S.No	Designation of concrete mix	Total volume fraction (V_f)in concrete	Total volume fraction (VF) of Polypropylene fibers (PP)	Total volume fraction (VF) of PET fibers
1	M1	No fibers	No fibers	No fibers
2	M2	1%	1%	0%
3	M3	1%	0%	1%
4	M4	1%	0.5%	0.5%
5	M5	1%	0.25%	0.75%
6	M6	1%	0.75%	0.25%

III. CASTING OF CONCRETE SAMPLES

All mould are cleaned and oiled from inner surfaces. Then the moulds are filled and compacted as per standard procedures. Each mould is filled in three layers and each layer is compacted with the help of electrically operated table vibrator available in laboratory. The moulds top surface is finished and leveled with help of standard trowels manually. It is done after suitable setting of concrete required for proper finishing. The moulds are opened manually with the help of spanner after 24 hours of casting. The detail of the concrete samples for each test is given in table 02 below:-

TABLE 2: Detail of concrete samples

Type of test	Size of sample	Total Nos. of samples	For 7 days testing	For 28 days testing.	Remarks
Compressive strength.	Cube 150 mm*150 mm*150 mm	36	18	18	18 No's of samples for each mix
Flexural strength.	Prism/ Beam 100 mm*100 mm*500 mm	36	18	18	
Split tensile strength	Cylinder Diameter 100 mm ,length 200 mm	36	18	18	
	Total samples to cast	108			

IV. RESULTS AND DISCUSSION

A. *Workability of concrete:*

The workability of the six concrete mixes is measured using slump flow test and compaction factor test. The results of the slump flow test are presented in table 03 and the results of Compaction factor test is presented in table 04 below:-

TABLE 3: Slump test results

Type of Mix	Slump in mm	Remarks	Type of concrete
M1	20 mm	Control Mix	plain
M2	5 mm	With 1% PP fibers	Fiber reinforced
M3	14 mm	With 1% PET fibers	Fiber reinforced
M4	10 mm	With 0.5%PP fibers +0.5%PET fibers	Hybrid fiber reinforced
M5	12 mm	0.25%PP fibers +0.75%PET	Hybrid fiber reinforced
M6	8 mm	0.75%PP fibers +0.25% PET	Hybrid fiber reinforced

TABLE 4: Compaction factor test results

Mix	Weight of empty cylinder (W1)(gram)	Weight of loose concrete + cylinder W2(gram)	Weight of compacted concrete +cylinder W3 (gram)	Compaction factor =W2-W1/W3-W1	Remark
M1	4924	14592	16922	0.806	Control mix
M2	4924	13180	16012	0.744	With 1% PP fibers
M3	4924	13821	16134	0.794	With 1% PET fibers
M4	4924	12850	15140	0.776	With 0.5% PP fibers +0.5%PET fibers
M5	4924	13980	16350	0.790	0.25%PP fibers +0.75%PET
M6	4924	12946	15120	0.786	0.75%PP fibers +0.25% PET

B. *Discussion on workability of concrete:*

Workability observed with slump test for M2 (with 1% PP fibers) concrete mix is 25% w.r.t M1 (control mix), M3 (with 1% PET fibers) concrete mix is 70%, M4 (0.5% PP fibers and 0.5% PET fibers) concrete mix is 50%, M5 (0.75% PET fibers and 0.25% PP fibers) concrete mix is 60%, and for M6 (with 0.75% PP fibers and 0.25% PET fibers) is reduced to 40%. The results show that the workability of concrete (M3 & M5) mix with higher proportion of PET fibers are more workable as compared to concrete mix containing higher proportions of PP fibers (M2 & M6). This higher reduction in slump containing more PP fibers may be attributed to the higher specific surface area of PP fibers compared to PET fibers. This increase the demand of water in mix for complete lubrication of PP fibers thereby increasing the friction between fibers and aggregates. Figure 01 show that with the increase in volume fraction of PP fibers from 0% to 1.0% the loss in slump have increase from 30% for M3 to 75% for mix M2 which contains only PP fibers with reference to the control mix. Similarly figure 02 shows that with increase in volume fraction of PET fibers from 0% to 1.0 % the loss in slump have decreased from 75% for mix M2 to 30% for mix M3 containing only PET fibers with reference to control mix. Similarly results have been obtained by the compaction factor test for workability, which has been elaborated in figure 03 and 04. The mix containing higher volume fraction of PET fibers (M3 and M5) has less loss of workability compared to the mix containing higher volume fracture of PP fibers (M2 & M6). Hence workability of M5 mix concrete is more after the control mix concrete workability, and workability of other mixes is less then M1 & M5 etc.

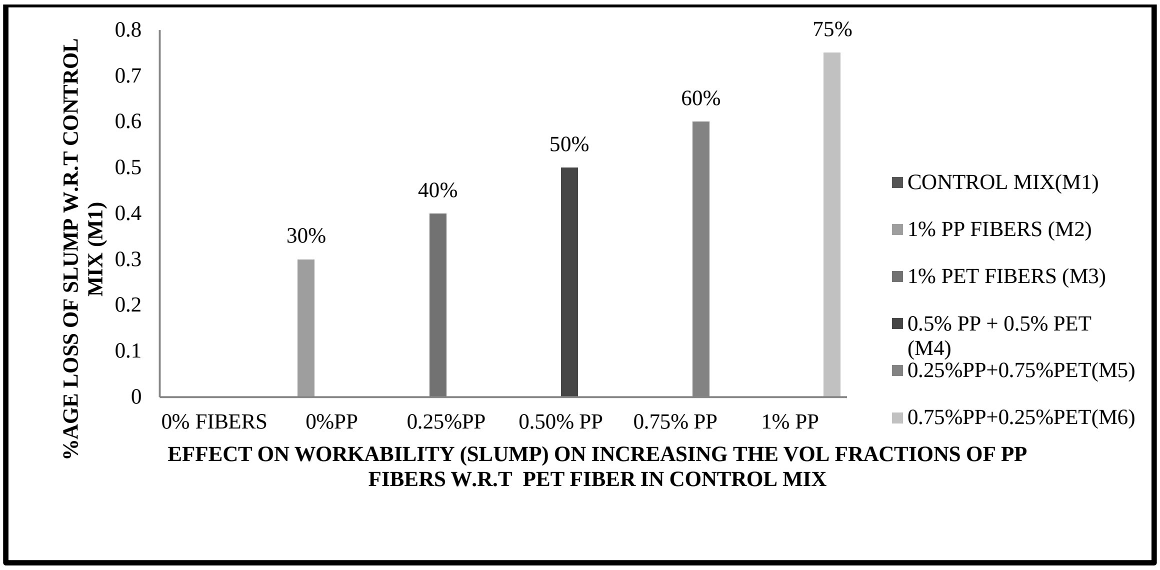

Fig. 1:- % age loss of Slump with addition of PP fibers in control mixes in different proportions

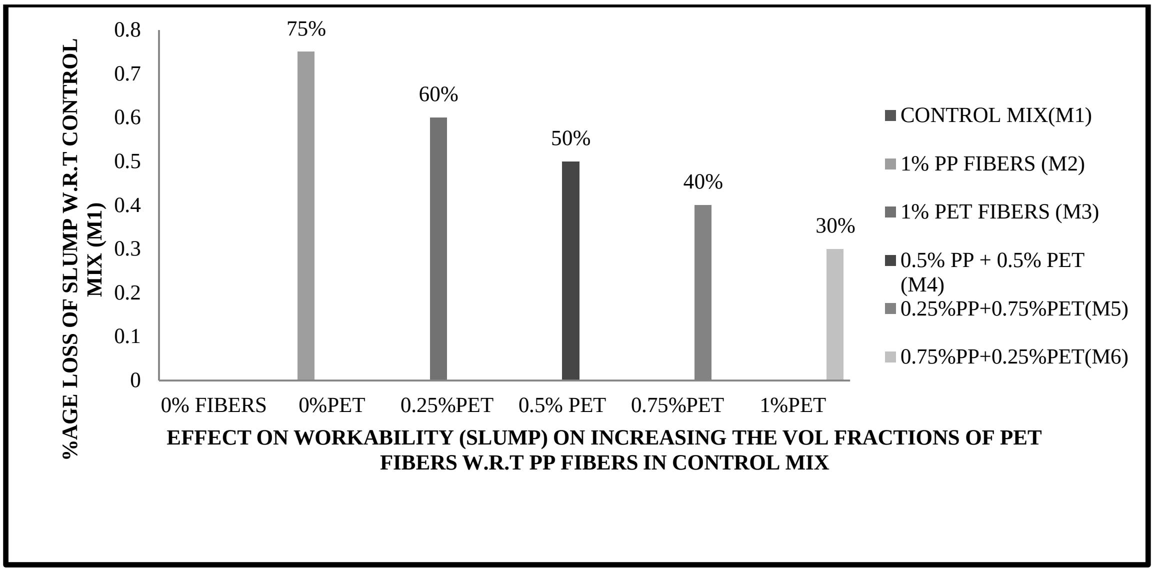

Fig. 2:- % age loss of Slump with addition of PET fibers in control mixes in different proportions

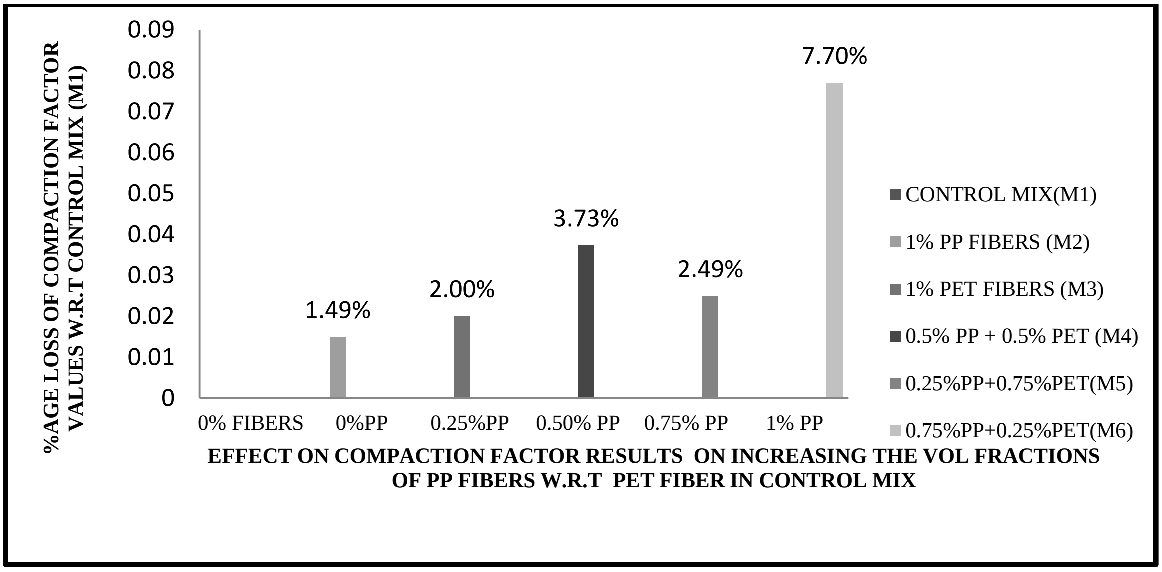

Fig. 3: % age loss of compaction factor values with addition of PP fibers in control mixes in different proportions

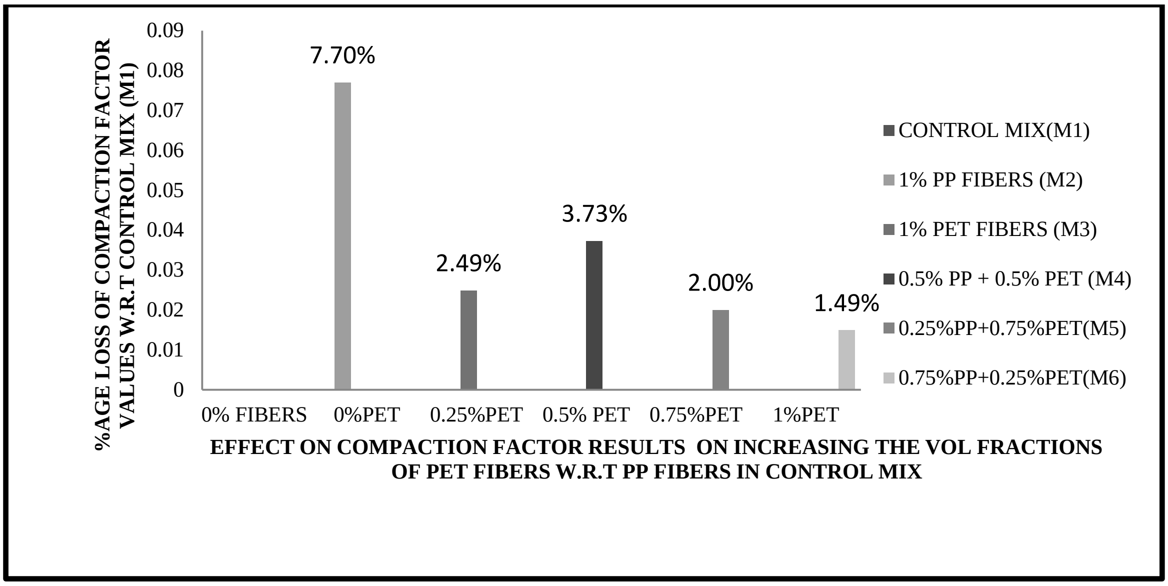

Fig. 4: % age loss of compaction factor values with addition of PET fibers in control mixes in different proportions

C. Compressive strength of concrete:

The average compressive strength of all concrete mixes at 7 days and 28 days are presented in Figure 05 below :-

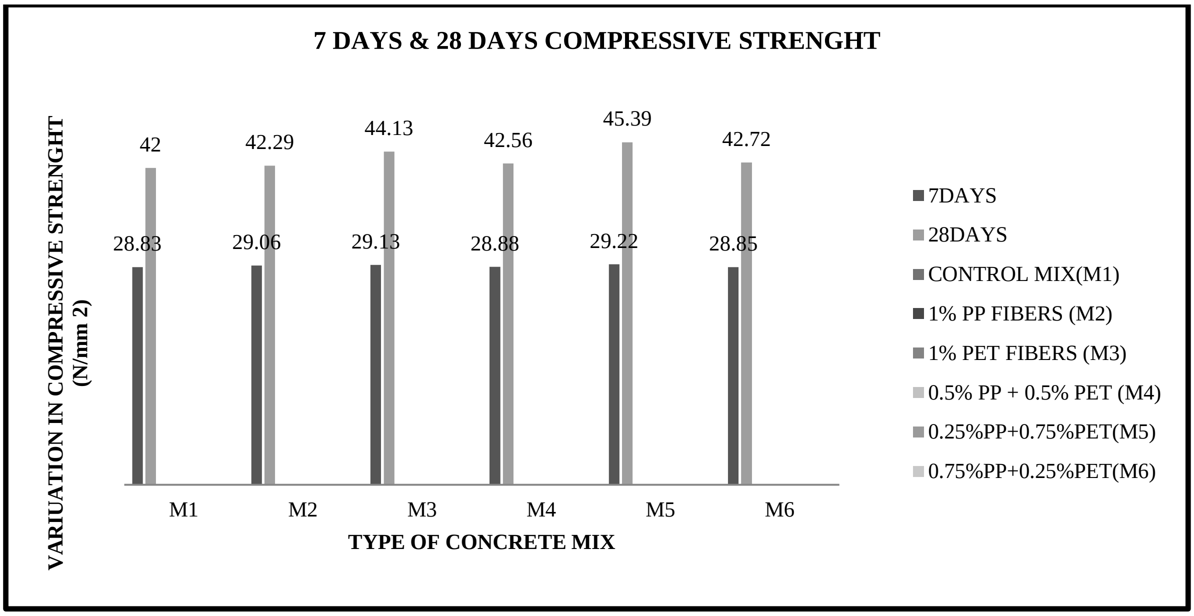

Fig. 5: 07 and 28 Days compressive strength of different mixes (N/mm^2)

D. Discussion on compressive strength of concrete:

The figure 06 shows the percentage increase in the 28 days average compressive strength compressive strength of fibers reinforced mixes M2 to M6 w.r.t to the control mixes (M1) containing no fibers.

The mixes M3 and M5 containing higher volume fraction of PET fibers i.e. 1.0% and 0.75% PET has an increase in average compressive strength by 5.07% and 8.07% with reference to control mix (M1). Whereas the mixes M2 & M6 containing higher volume fractions of PP fibers i.e. 1.0% and 0.75% PP fibers shows a marginal increase in average compressive strength by 0.69% and 1.71% with reference to control mix (M1).Thus the results of 28 days average compressive strength of hybrid fibers concrete mixes shows that the addition of PET fibers causes a better increase in compressive strength compared to the addition of PP fibers. This may be attributed to better interlocking effect of PET fibers in macro cracks whereas PP fibers more effective in arresting micro cracks at initial stage. The highest increase in the compressive strength among all the fiber reinforced mixes has been observed for the mix M5 containing 0.25% PP and 0.75% PET fibers i.e. 8.07% with respect to the compressive strength of control mix (M1).

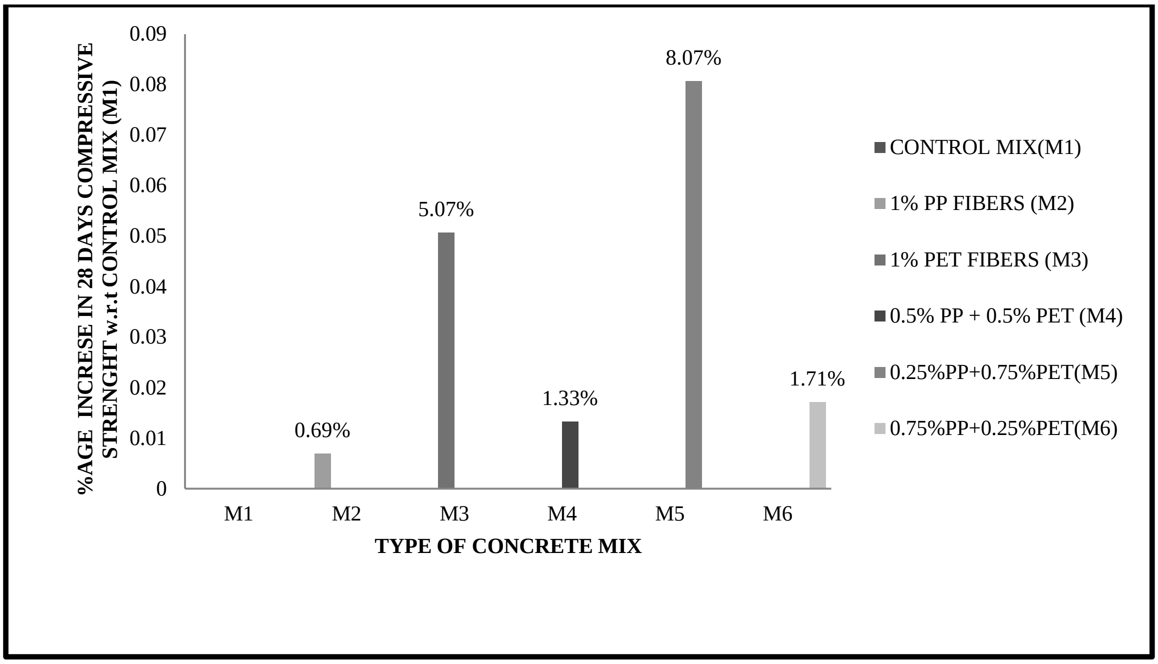

Fig. 6: % age increase in 28 days compressive strength for different mixes

E. ***Split tensile strength of Concrete:***

The average split tensile strength of all concrete mixes at 7 days and 28 days are presented Figure 07 below :-

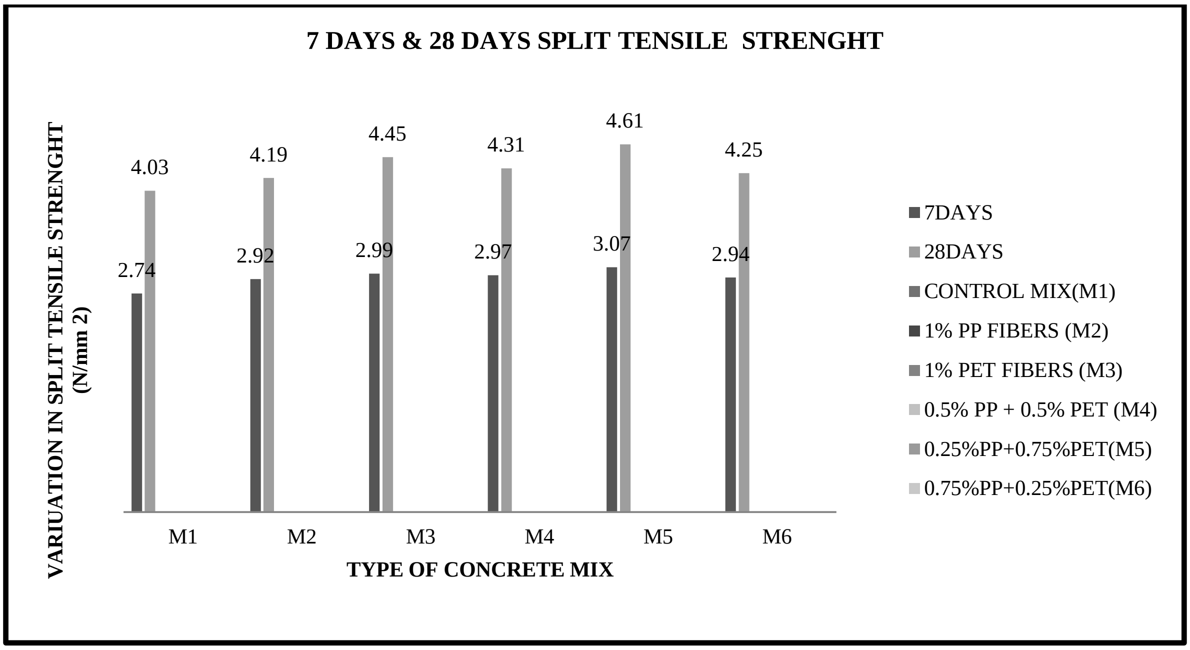

Fig. 7: 07 and 28 Days split tensile strength of different mixes (N/mm^2)

F. Discussion on split tensile strength of concrete:

The figure 08 shows the percentage increase in the 28 days average split tensile strength of fibers reinforced mixes M2 to M6 w.r.t to the control mixes (M1) containing no fibers. The mixes M3 and M5 containing higher volume fraction of PET fibers i.e. 1.0% and 0.75% PET has an increase in average split tensile strength by 10.42% and 14.39% with reference to control mix (M1). Whereas the mixes M2 & M6 containing higher volume fractions of PP fibers i.e. 1.0% and 0.75% PP fibers shows a marginal increase in average split tensile strength by 3.97% and 5.45% with reference to control mix (M1). Thus the results of addition of PET fibers cause a better increase in split tensile strength compared to the addition of PP fibers. The highest increase in the split strength among all the fiber reinforced mixes has been observed for the mix M5 containing 0.25% PP and 0.75% PET fibers i.e. 14.39% with respect to the split tensile strength of control mix (M1).

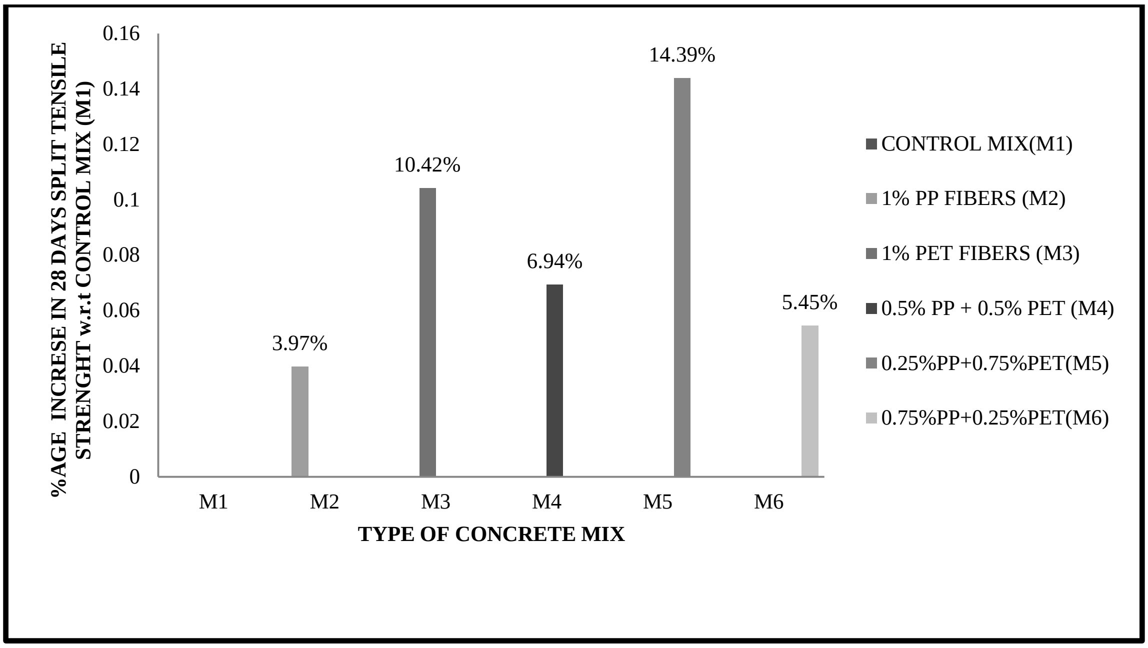

Fig. 8: % age increase in 28 days split tensile strength for different mixes

G. Flexural strength of concrete:

The beam/Prism average flexural strength of all concrete mixes at 7 days and 28 days are presented Figure 09 below:-

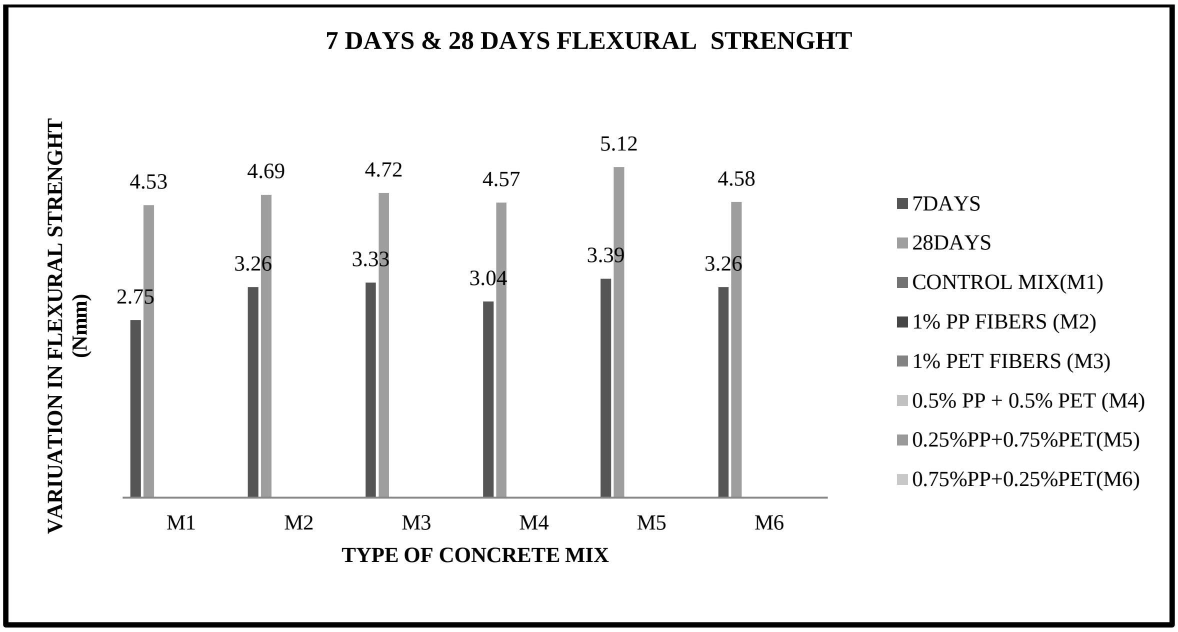

Fig. 9: 07 and 28 Days flexural strength of different mixes (Nmm)

H. Discussion on flexural strength of concrete:

The figure 10 shows the percentage increase in the 28 days average flexural strength of fibers reinforced mixes M2 to M6 w.r.t to the control mixes (M1) containing no fibers. The mixes M3 and M5 containing higher volume fraction of PET fibers i.e. 1.0% and 0.75% PET has an increase in average flexural strength by 4.19% and 13.02% with reference to control mix (M1). Whereas the mixes M2 & M6 containing higher volume fractions of PP fibers i.e. 1.0% and 0.75% PP fibers shows a marginal increase in average flexural strength by 3.53% and 1.10% with reference to control mix (M1). Thus the results of 28 days average flexural strength of hybrid fibers concrete mixes shows that the addition of PET fibers causes a better increase in flexural strength compared to the addition of PP fibers. The highest increase in the flexural among all the fiber reinforced mixes has been observed for the mix M5 containing 0.25% PP and 0.75% PET fibers i.e. 13.02% with respect to the split tensile strength of control mix (M1).

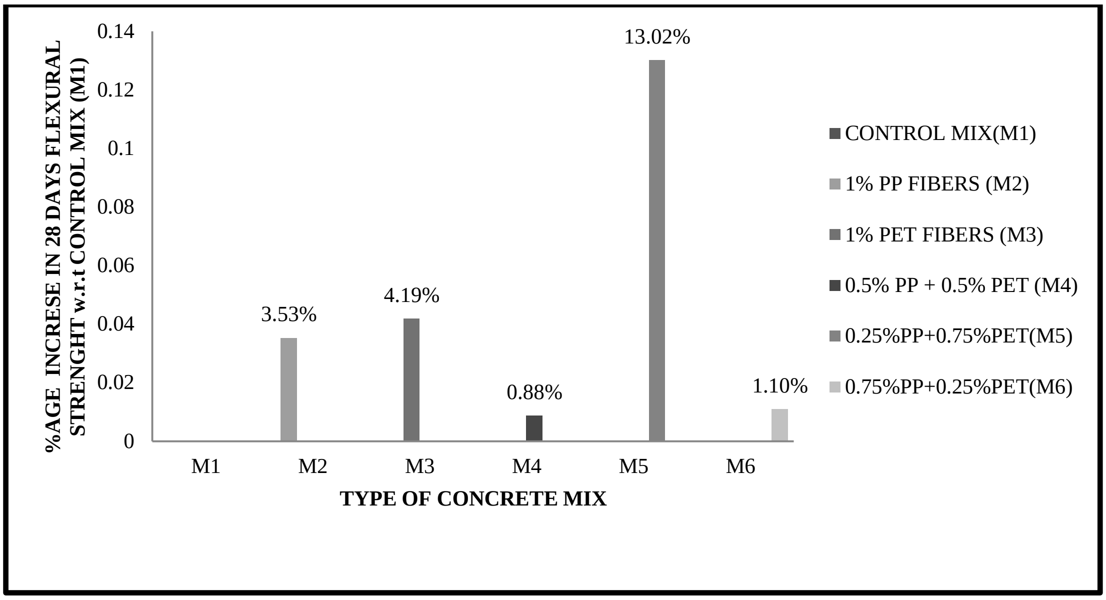

Fig. 10: % age increase in 28 days flexural strength for different mixes

V. COST EFFECTIVENESS OF PET-PP FIBERS REINFORCED CONCRETE

In this section, this improvement in strength is studied with reference to the cost involved in manufacturing of PET-PP fiber reinforced concrete mixes. The results are presented in the form of cost involved in enhancing a unit (i.e. 1Mpa) of strength of concrete. Figure N shows cost of different concrete mix with different percentage of fibers below:-

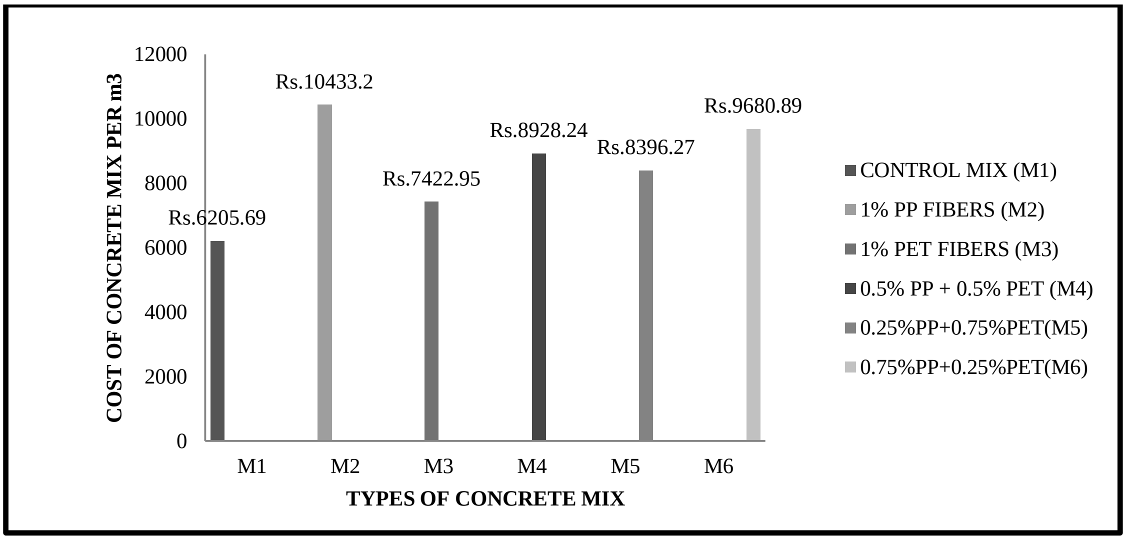

Fig. N: Showing variation in cost due to change in percentage of different fibers

The table 05 shows the percentage variation in cost of concrete per m^3 on addition of fibers.

TABLE 5: Percentage variation in cost of concrete mixes w.r.t normal concrete

Mix	M1	M2	M3	M4	M5	M6
Cost per m^3	6205.69	10433.20	7422.95	8918.24	8396.27	9680.89
Percentage variation	0%	68.12%	19.61%	43.71%	35.29%	56.00%

I. Cost effectiveness of various concrete mixes:

The cost effectiveness with respect to strength for various concrete mixes is calculated by dividing the strength of concrete mixes with their respective cost per cubic meter of concrete. Cost per unit strength (Mpa) is calculated for the various concrete mixes and is presented in table 06 below. For cost effectiveness only compressive strength is considered in this study as compressive strength is the foremost criteria to judge the strength of concrete.

TABLE 6:- Production cost of concrete per unit strength (Mpa) of concrete mixes

Mix type	Cost /Compressive Strength (Mpa)
M1	Rs. 147.75
M2	Rs. 246.70
M3	Rs. 168.20
M4	Rs.209.78
M5	Rs.184.98
M6	Rs.226.24

Table 7 below shows the increase in cost of concrete per unit strength of concrete with respect to control mix (M1).

TABLE 7:- Increase in cost of concrete per unit strength (Mpa)

Mix type	Increase in cost/Compressive Strength	%age increase in cost/strength(Mpa)
M1	-	
M2	Rs. 98.95	66.97%
M3	Rs. 20.45	13.8%
M4	Rs.62.03	41.98%
M5	Rs.37.23	25.19%
M6	Rs.78.49	53.12%

J. Discussion on cost effectiveness:

The results of the cost analysis of all six concrete mixes presented in table 06 and table 07 have shown that mixes with fibers are costlier then the control mix without fibers. The addition of polypropylene fibers has increase the production cost of concrete/strength (Mpa) more than the cost increased due to PET fibers. For mix M2 containing only PP fibers the production cost/strength (Mpa) is maximum i.e. Rs 246.70 and production cost/strength is minimum for M3 containing only PET fibers i.e. Rs 168.20. The percentage increase in cost/strength for mix M2 is 66.97% with respect to the control mix M1.On comparing the PET-PP hybrid fiber reinforced concrete mixes (i.e. Mix M4, M5, M6) it is observed that the mix M5 with 0.25% PP and 0.75% PET involves minimum cost/strength i.e. Rs 184.98 compared to other two mixes M4 & M6. The percentage increase in cost/strength for mix M5 is minimum i.e. 25.19% w.r.t the control mix M1compared to 41.98% for mix M4 and 53.12% for mix M6. Also in the previous sections it has been observed that mix M5 has the maximum strength gain in compressive, flexural and split tensile tests. Thus it can be concluded that keeping in view the maximum strength gain and minimum cost/strength the mix M5 is the mix with an optimum fiber hybridization of PET-PP hybrid fiber concrete (0.75% PET fibers and 0.25% PP fibers).

VI. CONCLUSIONS

The major conclusions of this study are summarized below:-

1) The Workability of all fiber reinforced concrete mixes reduced with the addition of fibers. Although the addition of volume of fibers was same for all the mixes i.e. 1% volume concrete, but the effect of hybridization of two different fibers PET and polypropylene (PP) was evident from the results which shows a drop in workability in the range of 30% to 75% among the fiber reinforced concrete mixes .A higher decrease in the workability was observed in mixes with higher percentage of PP fibers i.e. M2 (1.0% PP) and M6 (0.75% PP) whereas a lower decrease was observed for mixes with higher percentage of PET fibers, i.e. M3 (1% PET) and M5 (0.75% PET).

2) The addition of PET fibers caused a greater increase in the 28 days average compressive strength of concrete i.e. up to 8.07%, compared to the addition of PP fibers i.e. up to 1.71% only w.r.t control mix.The mix M5 with 0.75% PET and 0.25% PP fibers has shown the maximum compressive strength gain (i.e 8.07%) in reference to the control mix.

3) The split tensile strength was higher for the mixes containing higher volume fractions of PET fibers (i.e. M3 and M5), whereas the increase in split tensile strength was marginal for mixes with higher volume fractions of PP fibers (i.e. M2

and M6).The mix M5 with 0.75% PET and 0.25% PP fibers has the maximum split tensile strength gain (i.e. 14.39%) in reference to control mix.

4) The results for flexural strength has shown the same trend as compressive strength and split tensile strength. The flexural strength gain was higher for mixes M3 and M5 containing higher fractions of PET fibers compared to mixes M2 and M6 containing higher fractions of PP fibers.

5) The cost analysis shows that the increase in cost/strength for mixes containing PP fibers was more (i.e. 41.98% to 66.97%) to achieve a marginal compressive strength gain of 0.69% to 1.71%. Whereas the increase in cost/strength for mixes containing PET fibers was lower i.e. 13.8% to 25.19% to achieve a compressive strength gain (M3) 5.07% to (M5) 8.07%.The mix M5 shows the inherit advantage of fiber hybridization which has maximum strength gain of 8.07% with minimum cost/strength of 25.19%. Thus a combination of 0.75% PET + 0.25% PP is the recommended by hybridization dosage to obtain the optimum advantage of cost and strength in concrete mixes.

VII. FUTURE SCOPE OF STUDY

In the light of above, the present study leaves scope for the technologists to further study the following aspects:-

1) The durability of PET-PP hybrid fiber reinforced concrete.
2) The investigation of effect of fatigue stresses on PET-PP hybrid fiber reinforced concrete.
3) The study of fracture mechanism of PET-PP hybrid fiber reinforced concrete.
4) Higher grades or lower grades of concrete can be analyzed by same study procedure.
5) Effect of admixtures with use of same study can be analyzed

REFERENCES

[1] Antonio Carlos Alves de Moraes, Verginia Reis Crispim, Romildo D. Toledo Filho, Francisco J.O. Ferreira, "Neutron radiographic testing of samples of special concrete containing recycled PET granules as aggregate", International nuclear Atlantic conference-INAC2011, October 24 to 28, 2011.

[2] Ms.K.Ramadevi, Ms. R. Manju, "Experimental investigation on the properties of concrete with plastic PET (Bottle) fibers as fine aggregates", International journal of emerging technology and advanced engineering, June 2012.

[3] Fernando Pelisser, Oscar Rubem Klegues Monted, Philippe Jean Paul gleize, Humberto Ramos Roman, "Mechanical properties of recycled PET fiber in concrete", material research, July/aug.2012 e pub July 31, 2012.

[4] Wan Mohd Nazmi Wan Abdul Rahman, Achmad fauzi abdul wahab, "Green pavement using recycled Polyethylene Terephthalate (PET) as partial fine aggregate replacement in modified asphalt", Malaysian technical university conference on engineering & amp; Elsevier, 2013.

[5] R.N.Nibudey, P.B nagarnaik, D.K.parbat & A.M.pande, "Strength prediction of plastic fiber reinforced concrete (M30)", International journal of engineering research and publications (IJERA), pp.1818-1825, Jan- Feb 2013.

[6] R.N.Nibudey, P.B nagarnaik, D.K.parbat & A.M.pande, "Strength and fracture properties of post consumed waste plastic fiber reinforced concrete", International journal of Civil Structural, Environmental and Infrastructure engineering research and development, Jun 2013.

[7] J.M.Irwan, S.K. faisal, N.Othman, Wan Ibrahim M.H, R.M. Asyraf, & M.M.K. Annas, "Performance of concrete using Light waste PET fiber", Trans tech publications, Switzerland pp. 352-355.

[8] K.Murahari, Rama Mohan Rao, "Effects of polypropylene fibers on the strength properties of fly ash based concrete", International journal of engineering science invention, pp.13-19, May 2013.