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A Study on Impact of Polypropylene (Recron 3S) Fibers on Compressive and Tensile Strength of Concrete

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Abstract

The use of blended cement is becoming common in these days owing to the attempts made by the researchers in the direction of utilization of materials, which are available in natural abundantly. The new additives fly ash and polypropylene (Recron -3s) fibers, which is tried in recent times without any scientific study was found to be satisfactory. While, there is much to be done in order to standardize the properties of the said additives. The experimental study of this investigation consists of design of M40 grade concrete mix. The mix was worked out giving certain proportions by keeping the obtained water- cement ratio constant as 0.40. Concrete blends, viz. conventional concrete blends with differing rates of fly ash (0, 20, 30 and 40%) as cement replacement material were examined. Simultaneously the fibers were varied from 0 - 1% for each of the fly ash replacement in the concrete mix. The compressive strength and split tensile strength test were carried out at the ages of 7, 28 and 56 days. The impact of fibers and fly ash as cement replacement material on mechanical properties were analysed and compared with conventional cement concrete. This paper briefly shows the compressive strength of cubes and tensile strength of cylinders of all the concrete blends explored at 7, 28 and 56 days.
Keywords: CAC-Hyperfluid plus [H1], Compressive strength, Fly ash, Polypropylene Recron-3s (fibers), Split tensile strength

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I. INTRODUCTION

A. *General:*

Concrete is a durable and flexible construction material. It is mostly utilized building material on the planet. It is not just strong, economical and takes the state of the frame in which it is set, but it is also aesthetically satisfying. Concrete has an extensive load bearing capacity with regards to compression load, yet the material is weak in tension. That is the reason why steel reinforcement bars are implanted in the material while building the structures. The steel bars take over the load when the concrete cracks in tension. The concrete also shields the steel bars for assaults from nature and counteract erosion to happen.

Concrete is a moderately weak material when subjected to normal stresses and impact loads. The tensile strength of concrete is less because of extension of micro cracks existing in concrete subjected to tensile stresses. Because of presence of fiber, the micro cracks are captured. The introduction of fibers is generally taken as an answer for developing concrete in perspective of upgrading its flexural and tensile strength. In the event that a solid strategy could be produced that repairs cracks in concrete consequently, this would increment and guarantee durability, usefulness of concrete structures gigantically and spare a great deal of cash. On the off chance that a solid strategy for self-healing could be created this would open an entire better approach for outlining concrete structures, in which toughness issues can be handled in an alternate and more practical way Obviously repair cost of breaks that create in concrete structures would go down. Yet in addition the extra steel that is utilized to restrict crack widths could likely be spared to a vast extent.

Appropriately designed and prepared concrete results in great quality, good strength and durability properties. Indeed, even such very much planned and arranged cement concrete blends under controlled conditions additionally have certain restrictions as a result of which the above properties of concrete are observed to be deficient for special circumstances and for certain unique structures. Thus variety of admixtures, likewise fly ash, Silica fume, rise husk ash, GGBS, stone dust and so forth, are utilized alongside cement in specific rates to improve the properties of the standard cement concrete.

Fly Ash is the most normally and bounteously available manufactured pozzolana. It is otherwise called Coal Ash, Pulverized Fuel Ash and Pozzolona. It is either grey or blackish grey in colour. As the specific gravity of fly ash particles rely upon its chemical composition, it is described by low specific gravity and lack of plasticity. Contingent upon the sort of coal burnt, its specific gravity changes from 2 to 2.6.

Fly ash is a by-product from coal industry got as a residue in powder form by burning coal in furnaces and locomotives. The disposal of fly ash is the one of the major issue for environmentalists as dumping of fly ash as a waste material may cause cause extreme ecological issue. Thusly, the use of fly ash as a mineral admixture in concrete as opposed to dumping it as a waste material can have incredible gainful impacts. It is evacuated by the clean accumulation framework as fine molecule deposit from the flue gasses before they are released into environment. These micron-sized earth components comprise fundamentally of silica, alumina and iron. At the point when blended with lime and water the fly ash shapes a cementatious compound with properties similar to that of Portland cement. Due to this similitude, fly ash can be utilized to supplant a segment of cement in the concrete, giving some particular quality focal points. Substantial extent of fly ash, which is delivered in India, can be favorably utilized as a part of cement and concrete.

It can be utilized especially in mass concrete applications where fundamental accentuation is to control the thermal expansion due to heat of hydration of cement paste and it also helps in reducing thermal and shrinkage cracking of concrete at early ages. The replacement of cement with fly ash in concrete also helps to conserve energy. Class-F fly ash is created by burning harder, more established anthracite and bituminous coal. It is pozzalonic in nature. It contains less than 10% lime, glassy silica and alumina. So as to create cementatious compound class-F fly ash requires cementing agent like hydrated lime or Portland cement in presence of water.

Reliance Industry Limited (RIL) has launched Recron 3s fibers with the target of enhancing the quality of plaster and concrete. Recron 3S is a modified polyester fiber. It is for the most part utilized as secondary reinforcing material in concrete and soil to expand their performance. The accompanying are the few features of fibers:

- It controls cracking
- Reduction in water
- Increase in flexibility

Chemical admixture is a substance which imparts high workability with an expansive decline in water (no less than 20%) for a given workability. A high range water decreasing admixture is also known as super plasticizer. Each variety of super plasticizer has characterized ranges for required amounts of concrete mix ingredients, along with corresponding impacts. Measurements required fluctuate for specific concrete mix and kind of Super plasticizer utilized.

At the point when cement mixes with water, cement particles dependably flocculate and agglomerate in view of Vander Waals forces and electrostatic attractive forces created by the electric charge on the surface of the particles. This outcomes in a lot of free water being caught in the flocs, which decreases the consistence of concrete. Water reducing agents and super plasticizers join to the cement particles, conferring a negative surface charge and subsequently causing electrostatic repulsion, which in turn breaks the flocculation and agglomeration, and free the caught water.

Hence an attempt has been made in the present investigation on replacement of cement with fly ash to certain percentages and simultaneously varying the % of fibers with respect to each fly ash replacement. To attain the set out objectives of the present investigations, the grade of concrete M40 mix have been taken as reference concrete. Hardened concrete is tested for strength properties such as Compressive strength and Split Tensile Strength. The variations of above strengths with variation in different % of fly ash and % of fibers have been studied.

B. *bjectives of the present study:*

This work is an attempt to study the various engineering properties of a concrete made with cement replaced by Fly ash. To maintain the engineering properties, a synthetic fiber namely Recron 3s fibers manufactured by Reliance Industry Limited, India (RIL), commonly available in the local retail market of India, has been used in various proportions.

The experimental investigations include basic tests for cement and conventional tests for concrete such as compressive strength and split tensile strength have been taken up. The objective of the present work is to develop concrete with good strength. For this purpose it requires the use of pozzalanic material like fly ash along with fiber. So the experimental program undertaken;

- To evaluate effective use of pozzalanic material with fiber to achieve the desire needs.
- To find optimum dosage of Recron 3s fibers to get maximum strength for the M40 grade concrete
- To prepare mix design of M40 grade for Experimental Analysis with 0% to 1% Poly Propylene (Recron 3S) fibers, cement, sand, aggregate, water and super plasticizers.
- To analyse compressive strength, split tensile strength of fibered concrete mix.
- To obtain the optimum Replacement % of pozzalanic with a variations in dosage of fiber.
- Comparison of results of compressive and split tensile strength.

II. MATERIALS AND METHODOLOGY

A. *Materials used:*

Different types of materials used for casting concrete specimens are

- 20 mm down size coarse aggregate.

- M- Sand as fine aggregate.
- OPC 53 Grade ultratech cement.
- Class F fly ash as a cementitious material.
- Water.
- Polypropylene (Recron-3S) Fibers.
- CAC–HYPERFLUID PLUS [H1] as super plasticizer.

B. *Methodology:*

Based on mixed design, concrete cubes of size 150 X 150 X 150 mm and concrete cylinders of size 150 mm diameter and 300 mm length were casted and kept for curing in water tank. Total volume of concrete used for the present study was 1.68 m^3. Totally 180 cubes and 180 cylinders were casted.

Compressive and split tensile strength of 7, 28 and 56 days cured concrete cubes and cylinders were tested. Most of the cubes and cylinders attained target strength of the mix design for a curing period of 7 days only. For 28 and 56 days the required strength was obtained as per mix design.

1) *Mixing:*

The constituents 20 mm coarse aggregates, M-sand, fly ash, water, admixture (CAC-H1) and Polypropylene (Recron–3S) fibers are mixed in a mixer by adding them one by one. Once it gets mixed well, workability test is carried out with the help of slump cone and then poured into the moulds for casting.

2) *Casting:*

Moulds used for casting specimens are well cleaned and its inner surface is oiled. Concrete is filled in to the cubes in two layers and into the cylinders in three layers, compacting each layer 25 times by using tamping rod. Cubes of size 150 X 150 X 150 mm, and Cylinders of size 150 mm diameter and 300 mm length were casted.

3) *Curing:*

After casting the concrete cubes and cylinders are kept without demoulding for 24 hours. Then the demoulded specimens were kept in water tank for a curing period of 7, 28 and 56 days. Then the specimens were removed from the water tank after respective curing days and were kept in the sun for drying.

4) *Tests on concrete cubes and cylinders:*

The cube and cylinder specimens were confined to compression and split tensile test respectively as soon as they were removed from the water tank after 7, 28 and 56 days curing days respectively.

a) Compressive strength test:

Compressive strength test on cubes was conducted according to IS: 516-1959. Testing was done using standard compressive testing machine that applied load within range of 0.14-0.324 MPa/sec. Total 180 cubes of size 150mm X 150mm X 150 mm were casted. Out of that each of 60 cubes were from 7, 28 and 56 days of curing period respectively. Below formula was used to calculate the compressive strength.

Compressive strength =load/area in Mpa.

Where load is in KN and Area in mm^2.

b) Split tensile strength test:

Split tensile strength test on cylinders was conducted according to IS: 5816-1999. Testing was done using standard compressive testing machine that applied load within range of 1.4–2.1 N/mm^2/Min. Total 180 cylinders of size 150 mm x 300 mm were casted. Out of that each of 60 cylinders were from 7, 28 and 56 days of curing period respectively. Below formula was used to calculate the Split tensile strength.

$$\text{Split tensile strength} = \frac{2P}{\pi dL} \text{ Mpa.}$$

Where P is the maximum load in Newton, d is the diameter in mm and L is the length of the specimen in mm. Fig.1 shows the cube and cylinder subjected compression and split tensile test in compressive testing machine used in the present study.

Fig. 1: Image of Cube and Cylinder specimen tested in Compressive Testing Machine (CTM).

III. RESULTS AND DISCUSSIONS

A. General:

In the present work the fibers were added in varying percentages. The workability of fresh concrete was varying as percentage of fibers were increasing. Without fibers that is for 0% fibers the workability was not so good enough, the concrete mix was bleeding. As the percentage of fibers increased the concrete mix started to become harder that is for 0.25% and 0.5% of fibers. But for more than 0.75% of addition of fibers it seemed that it required more water to get the workable mix. But this draw back was satisfied by addition of plasticizers and mix was made workable.

The slump obtained for the mix without fibers was more than the required slump. The required slump was obtained for 0.25% and 0.5% of addition of fibers, whereas for more than 0.75% addition of fibers to the mix the slump obtained was less. It means as the percentage of addition of fibers increases the slump decreases.

When the fly ash was added that is for 20% and 30 % replacement of cement the workability was good enough. But as the percentage of fly ash increased that is for 40% the mix started showing the presence of oil content due to the presence of silicon dioxide. Up to 20% not much of the oil content was observed. In the present study the effect of number of days required to achieve the target compressive and split tensile strength of cubes and cylinders was determined respectively.

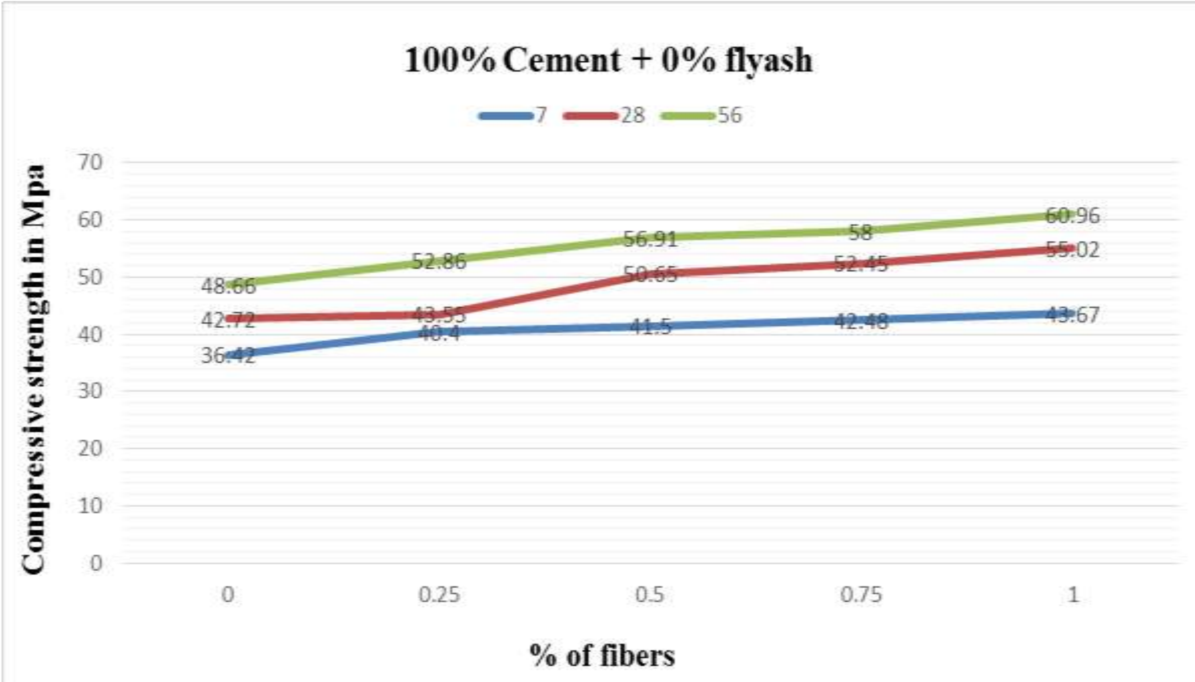
B. Compressive Strength Test Results:

The compressive strength test for cubes of size 150mm x 150mm x 150 mm was conducted as per IS: 516-1959 and the average compressive strength was determined. The compressive strength for M40 mix design exceeded the target compressive strength at 7 days itself. Significant increase in compressive strength occurs at 28 days curing with marginal increase at 56 days curing.

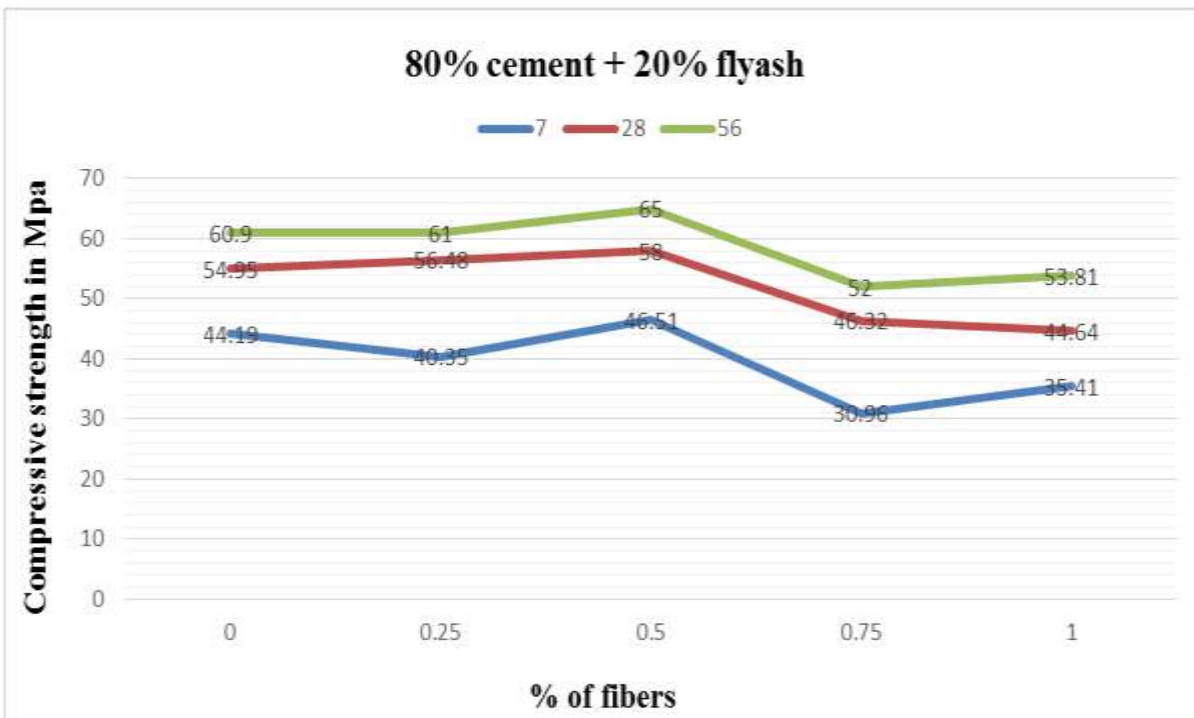
From the test results of compressive strength of cubes it is indicating that for 100% cement and 0% fly ash compressive strength is more for 1% of polypropylene Recron-3S fibers. Whereas for 20% and 30% fly ash replacement the compressive strength is maximum for 0.5% and 0.25% of Recron-3S fibers respectively and for 40% replacement the maximum compressive strength is for 0.75% of Recron-3s fibers. Results were tabulated as shown in the Table 1. Graph 1, 2, 3 and 4 summarizes the result in graphical form.

Table – 1
Average Compressive Strength of cubes in Mpa.

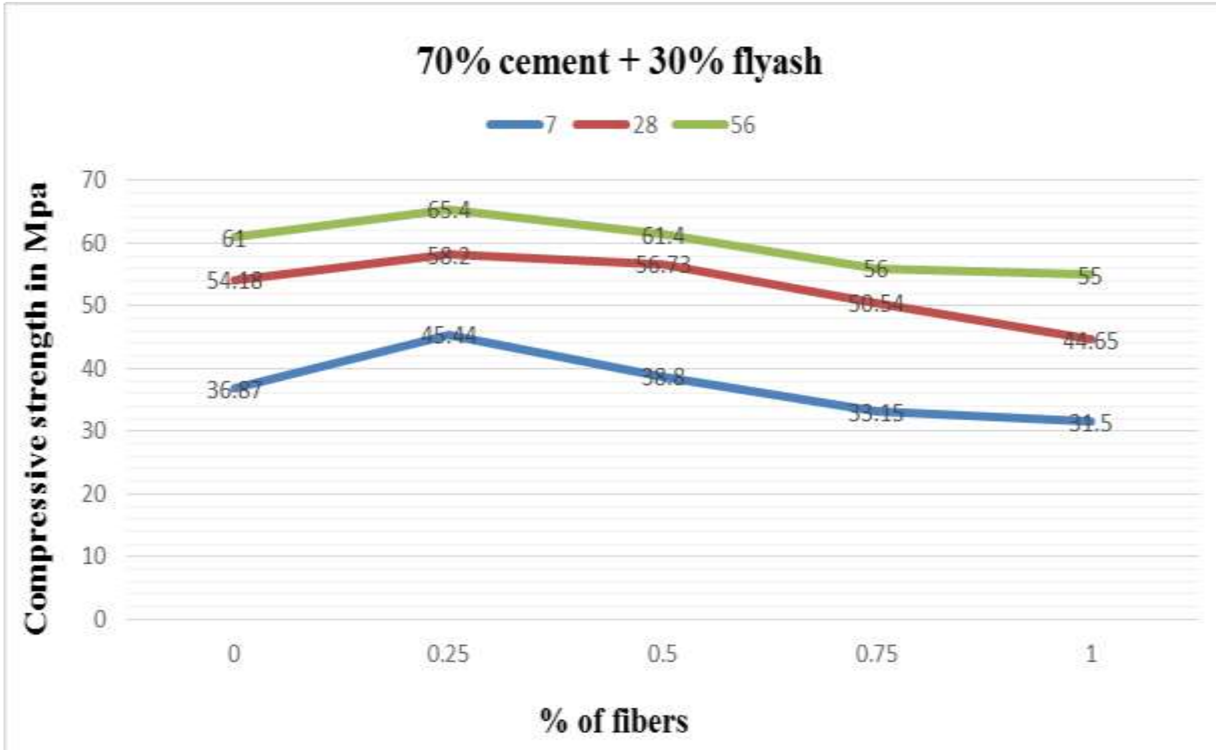
CEMENT CONTENT	*% OF FLYASH*	*% OF FIBERS*	*7 DAYS STRENGTH In Mpa*	*28 DAYS STRENGTH In Mpa*	*56 DAYS STRENGTH In Mpa*
100 %	*0 %*	*0*	*36.42*	*42.72*	*48.66*
		0.25	*40.40*	*43.55*	*52.86*
		0.5	*41.5*	*50.65*	*56.91*
		0.75	*42.48*	*52.45*	*58*
		1	*43.67*	*55.02*	*60.96*
80 %	*20 %*	*0*	*44.19*	*54.95*	*60.9*
		0.25	*40.35*	*56.48*	*61*
		0.5	*46.51*	*58*	*65*
		0.75	*30.96*	*46.32*	*52*
		1	*35.41*	*44.64*	*53.81*
70 %	*30 %*	*0*	*36.87*	*54.18*	*61*
		0.25	*45.44*	*58.20*	*65.4*
		0.5	*38.80*	*56.73*	*61.4*
		0.75	*33.15*	*50.54*	*56*
		1	*31.5*	*44.65*	*55*
60 %	*40 %*	*0*	*32.40*	*51.55*	*58.18*
		0.25	*41.59*	*52.14*	*59.06*
		0.5	*31.15*	*34.55*	*54.32*
		0.75	*34.49*	*59.60*	*65*
		1	*29.05*	*37.21*	*53.55*



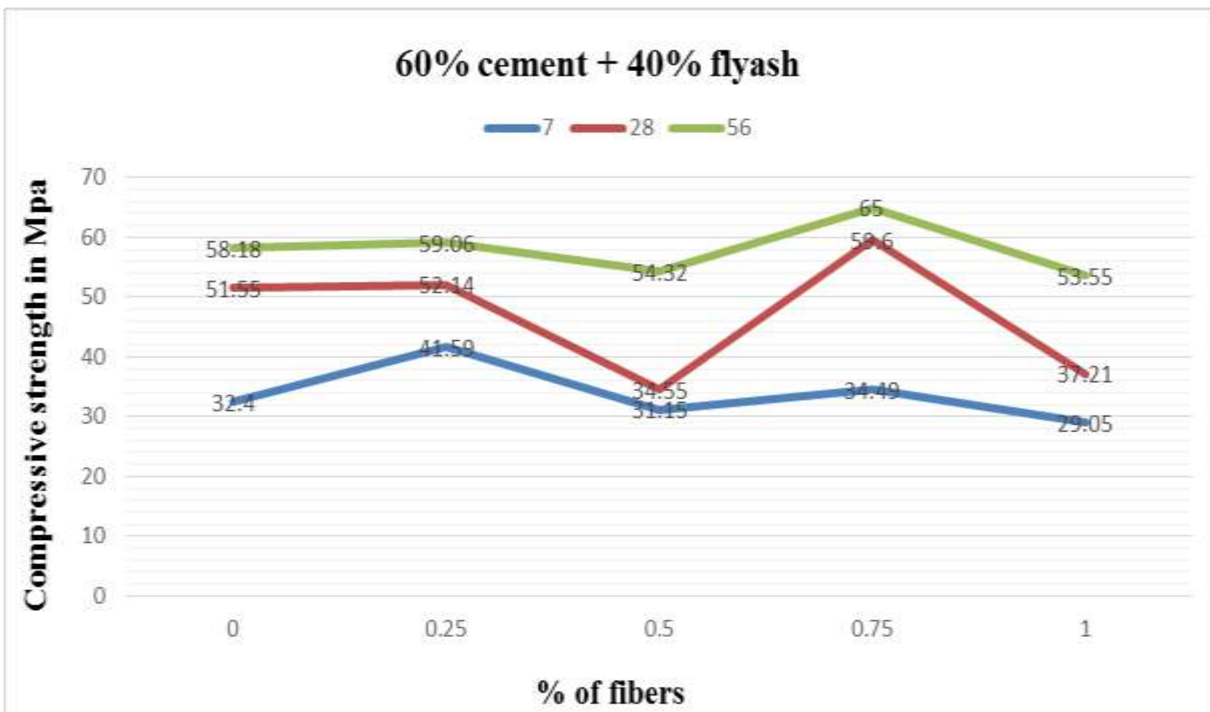
Graph 1: Compressive Strength results for 7, 28 and 56 days (100 % cement + 0 % fly ash)



Graph 2: Compressive Strength results for 7, 28 and 56 days (80 % cement + 20 % fly ash)



Graph 3: Compressive Strength results for 7, 28 and 56 days (70 % cement + 30 % fly ash)



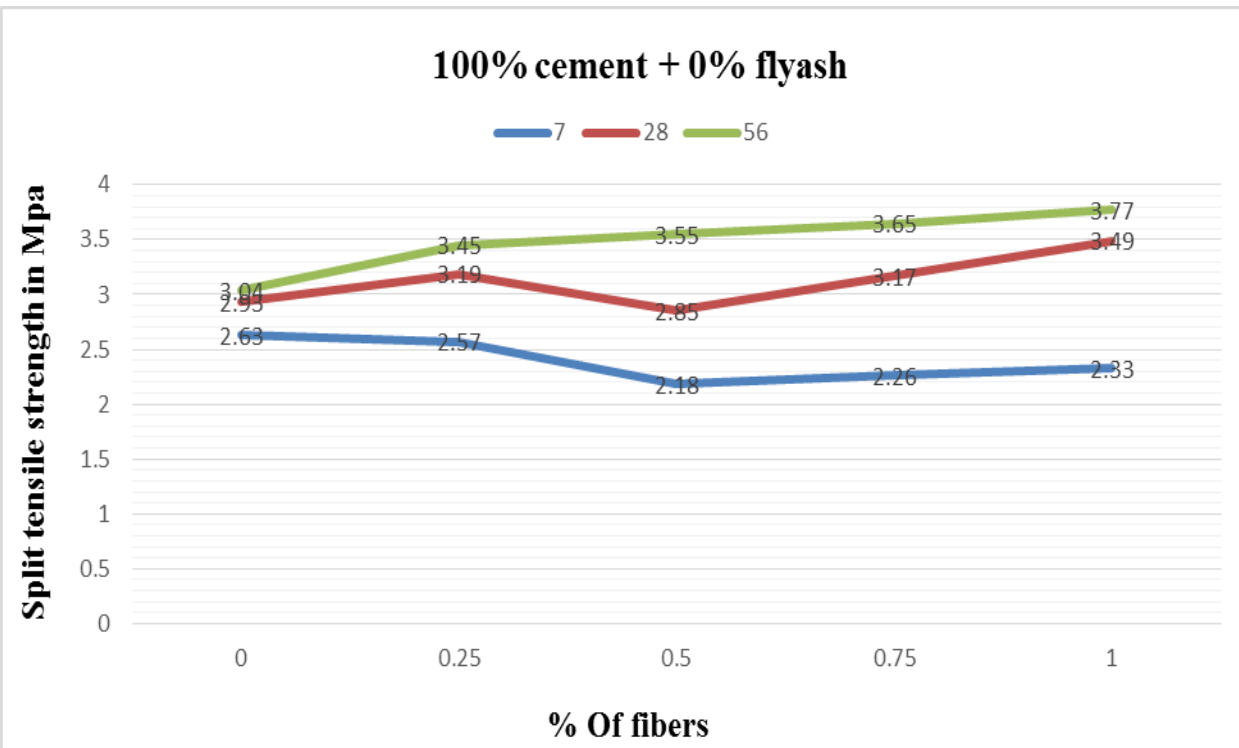
Graph 4: Compressive Strength results for 7, 28 and 56 days (60 % cement + 40 % fly ash)

C. Split tensile strength test results:

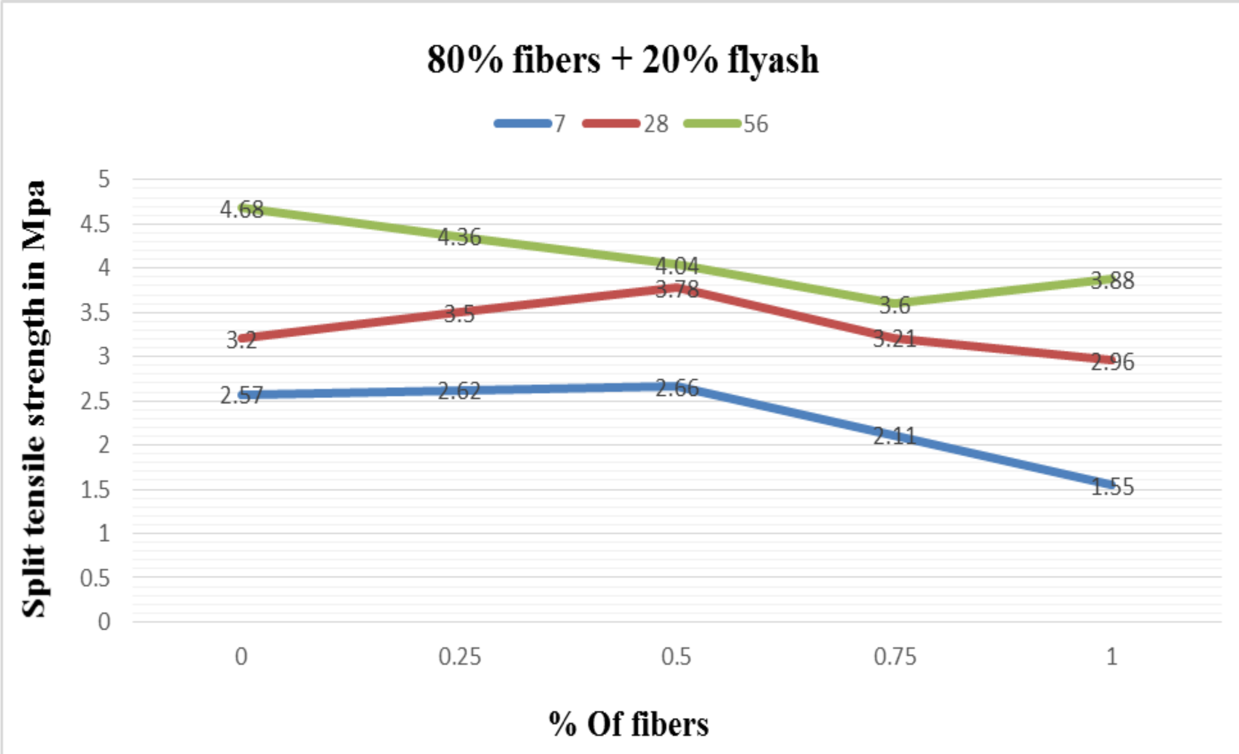
Split tensile strength test on cylinders (150mm x 300mm) was conducted according to IS: 5816-1999. The cylinders were tested to determine the average strength and the following results were obtained as shown in the Table 2. Graph 5, 6, 7 and 8 summarizes the result in graphical form.

Table – 2
Average Split Tensile Strength of Cylinders in Mpa.

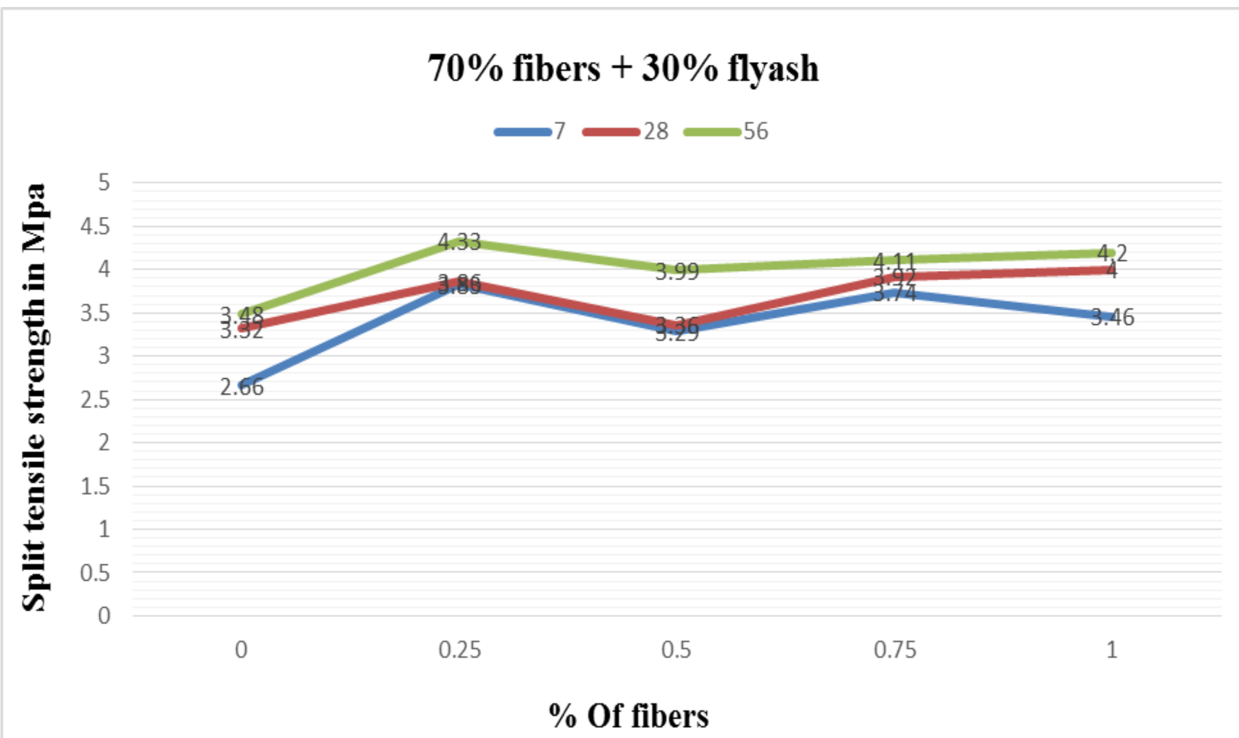
CEMENT CONTENT	% OF FLYASH	% OF FIBERS	7 DAYS STRENGTH In Mpa	28 DAYS STRENGTH In Mpa	56 DAYS STRENGTH In Mpa
100 %	0 %	0	2.63	2.93	3.04
		0.25	2.57	3.19	3.45
		0.5	2.18	2.85	3.55
		0.75	2.26	3.17	3.65
		1	2.33	3.49	3.77
80 %	20 %	0	2.57	3.2	4.68
		0.25	2.62	3.5	4.36
		0.5	2.66	3.78	4.04
		0.75	2.11	3.21	3.6
		1	1.55	2.96	3.88
70 %	30 %	0	2.66	3.32	3.48
		0.25	3.83	3.86	4.33
		0.5	3.29	3.36	3.99
		0.75	3.74	3.92	4.11
		1	3.46	4	4.2
60 %	40 %	0	3.25	4.23	3.76
		0.25	2.07	3.95	3.5
		0.5	2.74	4.07	3.33
		0.75	3.14	4.31	3.69
		1	2.66	4.03	3.64



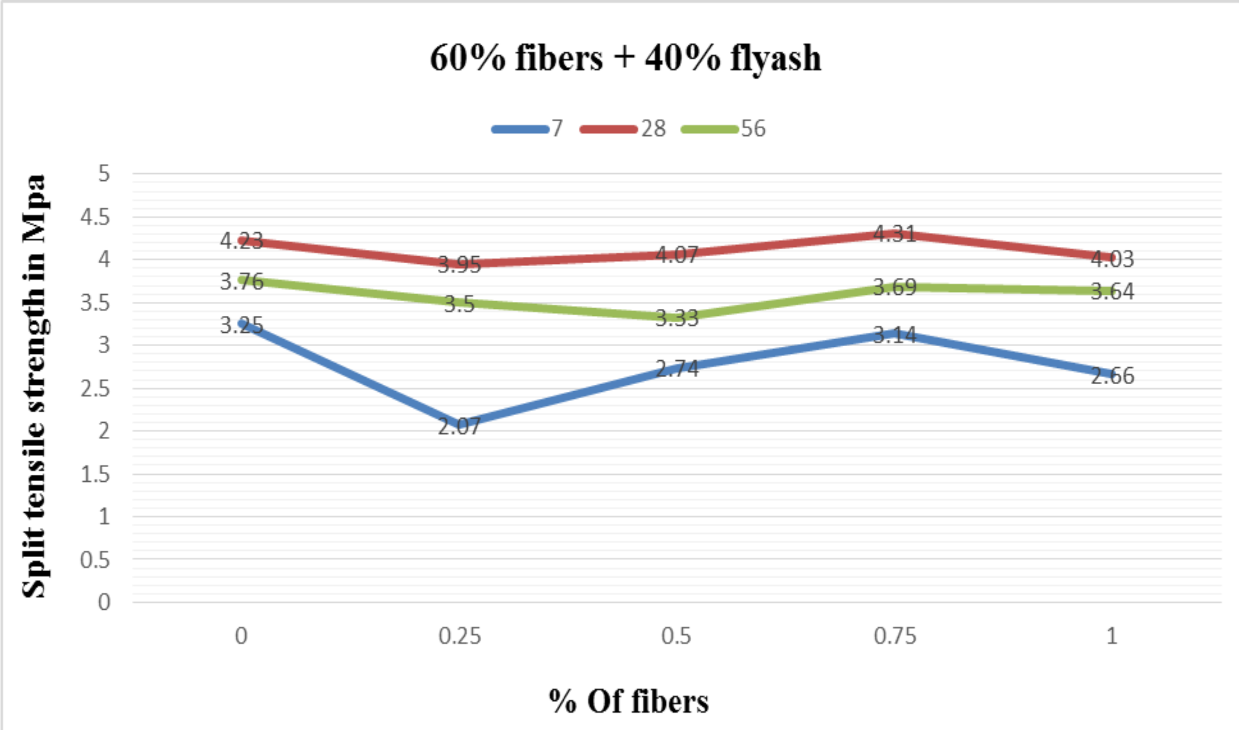
Graph 5: Split Tensile Strength results for 7, 28 and 56 days (100 % cement + 0 % fly ash.)



Graph 6: Split Tensile Strength results for 7, 28 and 56 days (80 % cement + 20 % fly ash.)



Graph 7: Split Tensile Strength results for 7, 28 and 56 days (70 % cement + 30 % fly ash.)



Graph 8: Split Tensile Strength results for 7, 28 and 56 days (60 % cement + 40 % fly ash.)

From the test results, the split tensile strength of cylinders is indicating that for 100% cement and 0% fly ash the split tensile strength is more for 1% of polypropylene (Recron-3s) fibers. Whereas for 20% and 30% fly ash replacement the split tensile strength is maximum for 0.5% and 0.25% of polypropylene (Recron-3s) fibers respectively and for 40% replacement the maximum split tensile strength is for 0.75% of Recron-3s fibers. This is due to high fly ash content and increased % of fibers by which the w/c ratio increases. The presence of silica in fly ash reacts with free lime either from cement or from any other source forming higher order hydrated products leading to increased tensile strength.

IV. Conclusion

Based on the experimental study following general concluding remarks can been drawn:

1) For concrete without addition of polypropylene (Recron-3s) fibers, concrete has high workability and good slump for all the mix proportions.
2) For concrete with addition of polypropylene (Recron-3s) fibers, as the amount of fibers content increases (0.25%, 0.5%, 0.75% and 1%) the workability decreases.
3) For 20% and 30% fly ash content the compressive and split tensile strength is more for 0.5% and 0.25% fibers addition respectively and for 40% fly ash the compressive and split tensile strength is more for 0.75% fiber content. Beyond 0.75% addition of fibers there is no significant increase in the strength for all the mixes containing fly ash.
4) Usage of polypropylene (Recron-3s) fibres will reduce the cost of maintenance by reducing the micro-cracks and permeability and hence the durability will increase. It also reduces the segregation.
5) For 28 days and 56 days curing, there is no significant change in compressive and split tensile strength.
6) Microstructural behaviour of concrete influence the strength characteristics of mix and also influence the compressive strength and split tensile strength of mixes.

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