Experimental Investigation on Mechanical Properties of Flyash Concrete and Flyash Fiber Reinforced Concrete

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ABSTRACT

The present Experimental investigation is to study the Mechanical Properties of the Fly ash concrete reinforced with steel fibers. The concrete composite comprises of steel fibers in different percentages and partial replacement of cement in different proportions. Steel fibers varied from 0%, 0.5%, 1% and 1.5% by weight of cement and replacement of fly ash varied from 0%, 10%, 20%, 30% and 40% by weight of cement. Specimens were tested for 28 days, 60 days and 90 days and behaviour of the flyash concrete, steel fiber reinforced concrete and fly ash concrete reinforced with steel fibers were studied. When the specimens were tested for 28 days strength, reduction in the Compressive strength, Split tensile strength and Flexural strength were observed, while the 90 days strength of the specimens were found to increase considerably. Based on the test results on control specimens, it was found that improvement in strength of concrete is achieved with a optimum steel fiber content of 1.5% and replacement of cement upto 30% by fly ash. The investigation programme included the determination of the optimum fiber content which can be provided in the concrete composites. Optimum fiber content was determined based on the Compressive strength, Split tensile strength, Flexural strength of the standard specimens. As the steel fiber percentage selected for our investigation is upto 1.5% by weight, it is suggested that this percentage may be increased to explore the possibility of using more steel fibers in fly ash concrete.

***Keywords* -** Steel Fiber reinforced concrete, Flyash fiber reinforced concrete, Compressive strength, Split tensile strength, Flexural strength.

I. INTRODUCTION

Concrete is the most widely used construction material and has high compressive strength. But it is very brittle due to weak tension, flexure and impact strength and has low resistance against cracking. One method to improve the brittle behavior of the concrete is the addition of small fibers in concrete with randomly distributed. Concrete so reinforced is called Fiber Reinforced Concrete (FRC). The main reason for incorporating fibers into a cement matrix is to increase the tensile strength, the energy absorption capacity, toughness, flexural strength of concrete and also it improves the cracking deformation characteristics of the concrete composite. Today, the industrial and agricultural waste by products such as fly ash and rice husk ash are used as Supplementary Cementitious materials in concrete. The incorporation of Supplementary Cementitious materials not only improve the mechanical properties of concrete and also reduce the cement consumption by replacing part of cement with these pozzolanic materials.

Many researchers have extensively researched the effects of fiber reinforcement on the properties of concrete. The tensile strength [1] of steel fiber reinforced concrete was higher for the aspect ratio of 50 as compared to aspect ratio of 60 and 67 and the tensile strength increased from 9% to 29% through utilization of steel fibers in 0%, 1%, 2% and 3% volume fractions. The flexural fatigue behaviour [2] of steel fiber reinforced recycled aggregate concrete had a increase in flexural strength of about 15% with the addition of steel fiber in concrete. The High Strength Concrete (HSC) provided the considerable improvement in compressive strength [3] for fiber content upto 1% compared to that of Normal Strength Concrete (NSC) and Medium Strength Concrete (MSC) in which the addition of fibers enhances the splitting tensile strength of NSC, MSC and HSC and increase the modulus of rupture in NSC compared to that of MSC and HSC for the fiber content ranges from 0% to 15% by volume of the concrete matrix. The flexural strength [4] of steel fiber reinforced concrete was higher at 3% by volume of fibers as compared to 0%, 1% and 2% by volume of fibers and flexural strength increases from 13% to 48.35% through utilization of steel fibers. Usage of steel fibers in concrete [5] increases the compressive strength of concrete by about 4% to 19% and also increases the split tensile strength and flexural strength of concrete with steel fibers of 0.5%, 1% and 1.5% by volume of concrete. The addition of steel fiber has a little reduction in compression strength but has a little increase [6] on splitting tensile strength and greatly influences the flexural strength and 1% fiber volume was recognized as the best fiber volume for both economical and strength aspects among the different fiber volume by a ratio of 0%, 0.7%, 1% and 1.5%. The flexural toughness of concrete [7] was found to increase considerably when steel and synthetic fibers were used.

The present Experimental investigation is to study the Mechanical Properties of fiber reinforced concrete with partial replacement of cement with fly ash with addition of steel fibers in different percentages. The fly ash fiber reinforced concrete composites specimens are tested for compressive, split tensile and flexural strength as per IS specifications. The results are compared with the control specimens that contains without fly ash and without steel fibers. With the appropriate interpretation of the obtained results, it can be possible to determine the optimum steel fiber percentage in fly ash concrete.

II. Material and experimental methods

2.1 Materials used

The cement used for the concrete mixtures was 53 grade Ordinary Portland cement conforming to IS: 12269. The specific gravity of the above cement was found to be 3.14. Vaigai River sand passed through 4.75 mm IS sieve was used as the fine aggregate with specific gravity of 2.65 and fineness modulus of 2.64. The hard broken granite stone passing through 12.5 mm IS sieve and retain on 4.75 mm IS sieve was used as the coarse aggregate with the specific gravity of 2.70. Fly ash procured from the Thermal Power Station at Tuticorin was used and it was tested in the Regional Testing Laboratory, Madurai. The Chemical properties of fly ash were listed in Table No 1. The hooked end steel fibers of length 35mm and diameter 0.5mm with aspect ratio of 70 were used in this study.

Table No.1 CHEMICAL PROPERTIES OF FLYASH

Sl. No.	Characteristics	Results
1	Silicon-di-Oxide (as SiO_2) + Aluminium Oxide (as Al_2O_3) + Iron Oxide (as Fe_2O_3), % by mass	85.94
2	Silica (as SiO_2), % by mass	60.21
3	Magnesium Oxide (as MgO), % by mass	1.99
4	Total Sulphur as Sulphur tri Oxide (SO_3), % by mass	2.19
5	Available Alkali as Sodium Oxide (Na_2O), % by mass	0.39
6	Loss on Ignition, % by mass	2.05
7	Moisture content, % by mass	0.28

2.2 Test Program

In this experimental work, concrete specimens were cast with and without fibers. Steel fibers are varied from 0%, 0.5%, 1% and 1.5% by weight of cement and partial replacement of cement with 10%, 20%, 30% and 40% Fly ash by weight of cement is considered. The concrete mix M20 is used in this investigation. The control concrete contains without steel fibers and without fly ash. For each mix, nine numbers of Cubes, nine numbers of Cylinder, nine numbers of Beam were used to determine the Compressive, Spilt Tensile, Flexure strength of concrete for 28 days, 60 days and 90 days. The details of the Test specimens used for this investigation are shown in the Table No. 2.

2.3 Mixing and casting details

Concrete was mixed using a Tilting type mixer and specimens were casted using steel moulds, compacted by table vibrator. Specimens were demoulded 24 hours after casting and cured in water tank until the testing age of 28 days, 60 days and 90 days. The specimens were numbered as per the nomenclature before being placed under water for curing.

Table No.2 DETAILS OF THE SPECIMENS.

Mix No.	Steel fiber %	Fly ash %
C	0 %	0 %
S0F10	0%	10%
S0F20	0%	20%
S0F30	0%	30%
S0F40	0%	40%
S0.5	0 .5%	0 %
S1	1 %	0 %
S1.5	1.5 %	0 %
S0.5F10	0.5 %	10 %
S0.5F20	0.5 %	20 %
S0.5F30	0.5 %	30%
S0.5F40	0.5 %	40%
S1F10	1%	10%
S1F20	1%	20%
S1F30	1%	30%
S1F40	1%	40%
S1.5F10	1.5%	10%
S1.5F20	1.5%	20%
S1.5F30	1.5%	30%
S1.5F40	1.5%	40%

III. Test results and Discussion

3.1 Compressive strength test

The Compressive strength of concrete was tested as per IS Specifications using 150mm x 150mm x 150mm cubes uniaxially. The cubes were tested in the compression testing machine of 2000 KN capacity. The crack pattern at maximum load for cube is shown in Fig No.1. The compressive strength was calculated by dividing the maximum compressive load by the cross sectional area of the cube specimen on which the load was applied. Compressive strength results including Percentage comparison are shown in Table No. 3 and variation in the compressive strength is shown in Fig No. 5.

Fig No.1 Crack pattern at ultimate failure load of Cube specimen

3.1.1 For different proportions of flyash with 0% Steel fibers

Compressive strength of concrete with 10% flyash was found to decrease by about 7% and 1% than plain concrete for 28 and 60 days respectively. However, 90 days strength was found to increase by 16% than plain concrete. Compressive strength of concrete with 20% flyash was found to decrease by about 11% than plain concrete for 28 days. However, the strength was found to increase by 2% and 38% in 60 and 90 days respectively than plain concrete. Compressive strength of concrete with 30% flyash was found to decrease by about 17% and 6% than plain concrete for 28 and 60 days respectively. However, 90 days strength was found to increase by 50% than plain concrete. Compressive strength of concrete with 40% flyash was found to decrease by about 25% and 5% than plain concrete for 28 and 60 days respectively. However, 90 days strength was found to increase by 43% than plain concrete.

3.1.2 For different proportions of flyash with 0.5% Steel fibers

Compressive strength of concrete with 10% flyash was found to increase by about 9%, 14% and 24% than plain concrete for 28, 60 and 90 days respectively. Compressive strength of concrete with 20% flyash was found to decrease by about 3% than plain concrete for 28 days. However, the strength was found to increase by 7% and 45% in 60 and 90 days respectively than plain concrete. Compressive strength of concrete with 30% flyash was found to decrease by about 9% than plain concrete for 28 days. However, the strength was found to increase by 5% and 59% in 60 and 90 days respectively than plain concrete. Compressive strength of concrete with 40% flyash was found to decrease by about 22% than plain concrete for 28 days. However, the strength was found to increase by 7% and 50% in 60 and 90 days respectively than plain concrete.

3.1.3. For different proportions of flyash with 1% Steel fibers

Compressive strength of concrete with 10% flyash was found to increase by about 19%, 26% and 38% than plain concrete for 28, 60 and 90 days respectively. Compressive strength of concrete with 20% flyash was found to increase by about 8%, 22% and 57% than plain concrete for 28, 60 and 90 days respectively. Compressive strength of concrete with 30% flyash was found to increase by about 0.5%, 11% and 70% than plain concrete for 28, 60 and 90 days respectively. Compressive strength of concrete with 40% flyash was found to decrease by about 9% than plain concrete for 28 days. However, the strength was found to increase by 18% and 59% in 60 and 90 days respectively than plain concrete.

3.1.4 For different proportions of flyash with 1.5% Steel fibers

Compressive strength of concrete with 10% flyash was found to increase by about 31%, 40% and 53% than plain concrete for 28, 60 and 90 days respectively. Compressive strength of concrete with 20% flyash was found to increase by about 18%, 36% and 64% than plain concrete for 28, 60 and 90 days respectively. Compressive strength of concrete with 30% flyash was found to increase by about 6.5%, 16% and 75% than plain concrete for 28, 60 and 90 days respectively. Compressive strength of concrete with 40% flyash was found to decrease by about 2% than plain concrete for 28 days. However, the strength was found to increase by 30% and 67% in 60 and 90 days respectively than plain concrete.

3.1.5 For different proportions of steel fiber with 0% flyash

Compressive strength of concrete with 0.5% steel fiber was found to increase by about 13.5%, 13% and 13.5% than plain concrete for 28, 60 and 90 days respectively. Compressive strength of concrete with 1% steel fiber was found to increase by about 27%, 27% and 27% than plain concrete for 28, 60 and 90 days respectively. Compressive strength of concrete with 1.5% steel fiber was found to increase by about 19%, 18% and 18% than plain concrete for 28, 60 and 90 days respectively.

3.2 Split Tensile strength

The split tensile strength of concrete was tested as per IS Specifications using 150mm diameter x 300 mm height cylinder. The specimen was placed with its longitudinal axis in the horizontal position between the two plates of compression testing machine with plywood strips 3 mm thick, 12 mm wide and 300 mm long sandwiched between the plate and cylinder. Split Tensile strength results including Percentage comparison are shown in Table No. 4 and variation in the Split Tensile strength is shown in Fig No. 6.

3.2.1 For different proportions of flyash with 0% Steel fibers

Split tensile strength of concrete with 10% flyash was found to decrease by about 6% than plain concrete for 28 days. However the strength was found to increase by 1% and 2% in 60 and 90 days respectively than plain concrete. Split tensile strength of concrete with 20% flyash was found to decrease by about 1% than plain concrete for 28 days. However the strength was found to increase by 2% and 3% in 60 and 90 days respectively than plain concrete. Split tensile strength of concrete with 30% flyash was found to increase by about 3%, 6% and 19% than plain concrete for 28, 60 and 90 days respectively. Split tensile strength of concrete with 40% flyash was found to decrease by about 13%, 6% and 2% than plain concrete for 28, 60 and 90 days respectively.

3.2.2 For different proportions of flyash with 0.5% Steel fibers

Split tensile strength of concrete with 10% flyash was found to increase by about 0.3%, 4% and 5% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 20% flyash was found to increase by about 6%, 13% and 12% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 30% flyash was found to increase by about 8%, 10% and 25% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 40% flyash was found to increase by about 2%, 2% and 5% than plain concrete for 28, 60 and 90days respectively.

3.2.3 For different proportions of flyash with 1% Steel fibers

Split tensile strength of concrete with 10% flyash was found to increase by about 10%, 13% and 18% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 20% flyash was found to increase by about 14%, 20% and 20% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 30% flyash was found to increase by about 14%, 15% and 30% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 40% flyash was found to increase by about 10%, 16% and 22% than plain concrete for 28, 60 and 90days respectively.

3.2.4 For different proportions of flyash with 1.5% Steel fibers

Split tensile strength of concrete with 10% flyash was found to increase by about 18%, 24% and 26% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 20% flyash was found to increase by about 18%, 28% and 28% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 30% flyash was found to increase by about 20%, 20% and 31% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 40% flyash was found to increase by about 17%, 19% and 26% than plain concrete for 28, 60 and 90days respectively.

3.2.5 For different proportions of steel fiber with 0% flyash

Split tensile strength of concrete with 0.5% steel fiber was found to increase by about 4%, 4% and 5% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 1% steel fiber was found to increase by about 17%, 18% and 18% than plain concrete for 28, 60 and 90days respectively. Split tensile strength of concrete with 1.5% steel fiber was found to increase by about 13%, 15% and 15% than plain concrete for 28, 60 and 90days respectively.

3.3 Flexural strength

The static flexural strength of concrete was tested as per IS specifications using 100mm x 100mm x 500mm beam specimen under two point loading. The Flexural strength setup is shown in Fig No.2. The test was conducted on a Universal Testing Machine (UTM). Part of the Beam specimens after ultimate failure is shown in Fig No.3 and Cross section of the beam specimen after ultimate failure is shown in Fig No.4. The test results including Percentage comparison are shown in the Table No. 5 and variation in the Flexural strength is shown in Fig No. 7.

Fig No.2 Flexural strength setup

3.3.1 For different proportions of flyash with 0% Steel fibers

Flexural strength of concrete with 10% flyash was found to decrease by about 16% and 4% than plain concrete for 28 and 60 days respectively. However 90 days strength was found to increase by 5% than plain concrete. Flexural strength of concrete with 20% flyash was found to decrease by about 13% and 2% than plain concrete for 28 and 60 days respectively. However 90 days strength was found to increase by 10% than plain concrete. Flexural strength of concrete with 30% flyash was found to decrease by about 9% and 4% than plain concrete for 28 and 60 days respectively. However 90 days strength was found to increase by 10% than plain concrete. Flexural strength of concrete with 40% flyash was found to decrease by about 18% and 2% than plain concrete for 28 and 60 days respectively. However 90 days strength was found to increase by 1% than plain concrete.

3.3.2 For different proportions of flyash with 0.5% Steel fibers

Flexural strength of concrete with 10% flyash was found to decrease by about 7% than plain concrete for 28 days. However the strength was found to increase by 3% and 18% in 60 and 90 days respectively than plain concrete. Flexural strength of concrete with 20% flyash was found to decrease by about 7% than plain concrete for 28 days. However the strength was found to increase by 4% and 20% in 60 and 90 days respectively than plain concrete. Flexural strength of concrete with 30% flyash was found to increase by about 0%, 4% and 31% than plain concrete for 28, 60 and 90 days respectively. Flexural strength of concrete with 40% flyash was found to decrease by about 4% than plain concrete for 28 days. However the strength was found to increase by 4% and 10% in 60 and 90 days respectively than plain concrete.

3.3.3 For different proportions of flyash with 1% Steel fibers

Flexural strength of concrete with 10% flyash was found to decrease by about 2% than plain concrete for 28 days. However the strength was found to increase by 10% and 27% in 60 and 90 days respectively than plain concrete. Flexural strength of concrete with 20% flyash was found to increase by about 9%, 13% and 29% than plain concrete for 28, 60 and 90 days respectively. Flexural strength of concrete with 30% flyash was found to increase by about 9%, 17% and 46% than plain concrete for 28, 60 and 90 days respectively. Flexural strength of concrete with 40% flyash was found to increase by about 2%, 17% and 24% than plain concrete for 28, 60 and 90 days respectively.

Fig No.3 Part of the Beam specimens after ultimate failure

3.3.4 For different proportions of flyash with 1.5% Steel fibers

Flexural strength of concrete with 10% flyash was found to increase by about 0%, 17% and 31% than plain concrete for 28, 60 and 90 days respectively. Flexural strength of concrete with 20% flyash was found to increase by about 20%, 24% and 37% than plain concrete for 28, 60 and 90 days respectively. Flexural strength of concrete with 30% flyash was found to increase by about 15%, 24% and 52% than plain concrete for 28, 60 and 90 days respectively. Flexural strength of concrete with 40% flyash was found to increase by about 4%, 24% and 31% than plain concrete for 28, 60 and 90 days respectively.

3.3.5 For different proportions of steel fiber with 0% flyash

Flexural strength of concrete with 0.5% steel fiber was found to increase by about 6%, 6% and 4% than plain concrete for 28, 60 and 90 days respectively. Flexural strength of concrete with 1% steel fiber was found to increase by about 9%, 8% and 7% than plain concrete for 28, 60 and 90 days respectively. Flexural strength of concrete with 1.5% steel fiber was found to increase by about 7%, 7% and 5% than plain concrete for 28, 60 and 90 days respectively.

Fig No. 4 Cross section of the beam specimen after ultimate failure.

Table No. 3 Compressive strength results

Sl. No.	Mix No.	Steel fiber %	Fly ash %	Compressive strength N/mm^2			Comparison of % Improvement of flyash fiber reinforced concrete		
				28 days	60 days	90 days	28 days	60 days	90 days
1	C	0 %	0 %	26.50	26.71	26.86	0	0	0
2	S0.5	0.5%	0 %	30.08	30.31	30.51	13.50	13.47	13.58
3	S1	1 %	0 %	33.66	33.86	34.12	27.01	26.76	27.02
4	S1.5	1.5 %	0 %	31.51	31.54	31.66	18.90	18.08	17.87
5	S0F10	0 %	10 %	24.65	26.55	31.23	-6.98	-0.59	16.26
6	S0F20	0%	20 %	23.64	27.36	36.96	-10.79	2.43	37.60
7	S0F30	0%	30%	21.92	25.07	40.39	-17.28	-6.14	50.37
8	S0F40	0%	40%	19.77	25.39	38.39	-25.39	-4.94	42.92
9	S0.5F10	0.5 %	10 %	28.79	30.51	33.23	8.64	14.22	23.71
10	S0.5F20	0.5 %	20 %	25.78	28.65	38.96	-2.71	7.26	45.04
11	S0.5F30	0.5 %	30%	24.06	27.93	42.69	-9.20	4.56	58.93
12	S0.5F40	0.5 %	40%	20.77	28.65	40.39	-21.62	7.26	50.37
13	S1F10	1%	10%	31.51	33.66	36.96	18.90	26.02	37.60
14	S1F20	1%	20%	28.65	32.66	42.26	8.11	22.27	57.33
15	S1F30	1%	30%	26.64	29.65	45.55	0.52	11.00	69.58
16	S1F40	1%	40%	24.06	31.51	42.69	-9.20	17.97	58.93
17	S1.5F10	1.5%	10%	34.66	37.53	41.11	30.79	40.50	53.05
18	S1.5F20	1.5%	20%	31.23	36.24	44.11	17.84	35.67	64.22
19	S1.5F30	1.5%	30%	28.22	31.08	47.13	6.49	16.36	75.46
20	S1.5F40	1.5%	40%	25.93	34.81	44.84	-2.15	30.32	66.93

Fig No. 5 Compressive strength of Fly ash Concrete Reinforced with steel fibers

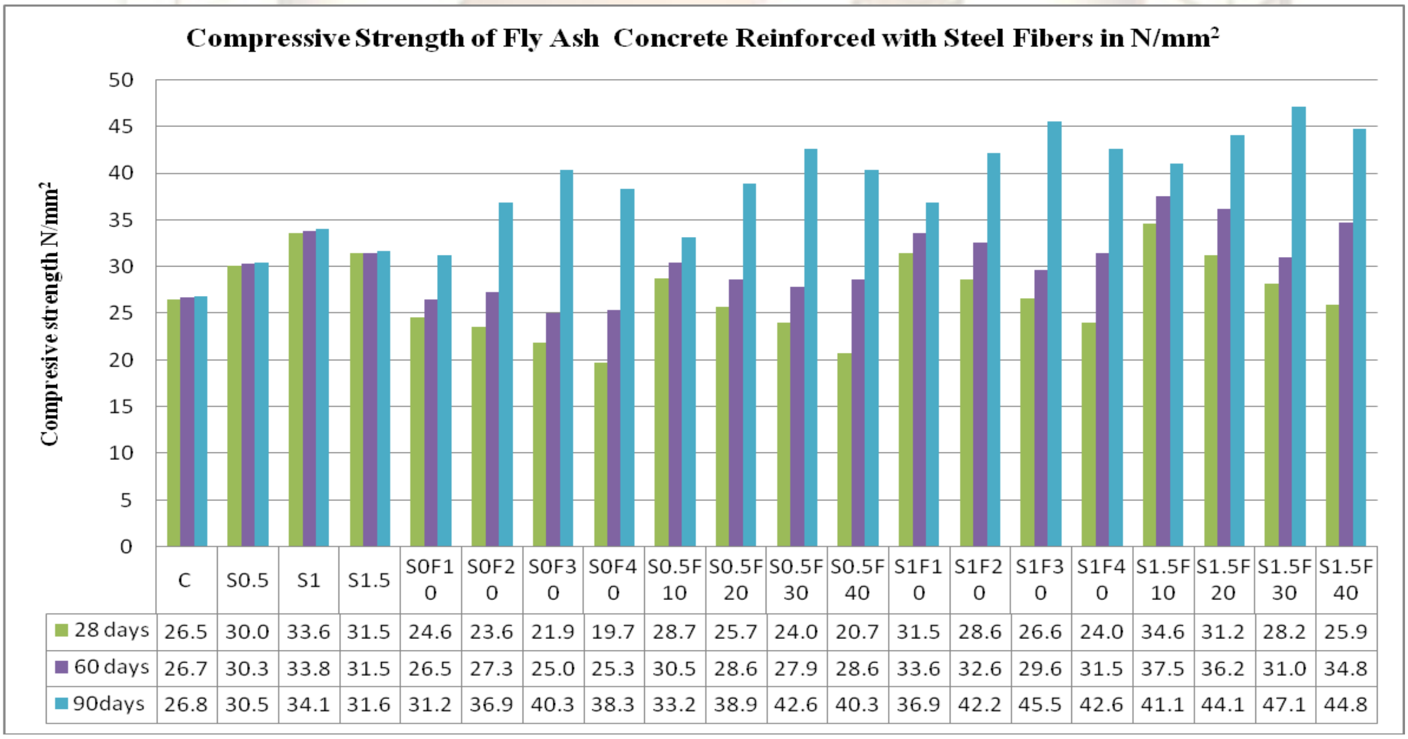


Table No. 4 Split tensile strength results

Sl. No.	Mix No.	Steel fiber %	Fly ash %	Split tensile strength N/mm^2			Comparison of % Improvement of flyash fiber reinforced concrete		
				28 days	60 days	90 days	28 days	60 days	90 days
1	C	0 %	0 %	2.92	2.94	2.97	0	0	0
2	S0.5	0.5%	0 %	3.04	3.06	3.11	4.10	4.08	4.70
3	S1	1 %	0 %	3.43	3.47	3.50	17.46	18.02	17.84
4	S1.5	1.5 %	0 %	3.31	3.39	3.42	13.35	15.30	15.15
5	S0F10	0 %	10 %	2.75	2.97	3.03	-5.82	1.02	2.02
6	S0F20	0%	20 %	2.88	3.01	3.06	-1.36	2.38	3.03
7	S0F30	0%	30%	3.02	3.12	3.54	3.42	6.12	19.19
8	S0F40	0%	40%	2.53	2.75	2.9	-13.35	-6.46	-2.35
9	S0.5F10	0.5 %	10 %	2.93	3.06	3.13	0.34	4.08	5.38
10	S0.5F20	0.5 %	20 %	3.09	3.31	3.34	5.82	12.58	12.45
11	S0.5F30	0.5 %	30%	3.15	3.24	3.72	7.87	10.20	25.25
12	S0.5F40	0.5 %	40%	2.99	3.00	3.12	2.39	2.04	5.05
13	S1F10	1%	10%	3.21	3.33	3.50	9.93	13.26	17.84
14	S1F20	1%	20%	3.32	3.54	3.57	13.69	20.40	20.20
15	S1F30	1%	30%	3.33	3.37	3.85	14.04	14.62	29.62
16	S1F40	1%	40%	3.21	3.42	3.62	9.93	16.32	21.88
17	S1.5F10	1.5%	10%	3.46	3.65	3.75	18.49	24.14	26.26
18	S1.5F20	1.5%	20%	3.44	3.77	3.81	17.80	28.23	28.28
19	S1.5F30	1.5%	30%	3.50	3.52	3.88	19.86	19.72	30.63
20	S1.5F40	1.5%	40%	3.41	3.49	3.75	16.78	18.70	26.26

Fig No. 6 Split Tensile strength of Fly ash Concrete Reinforced with steel fibers

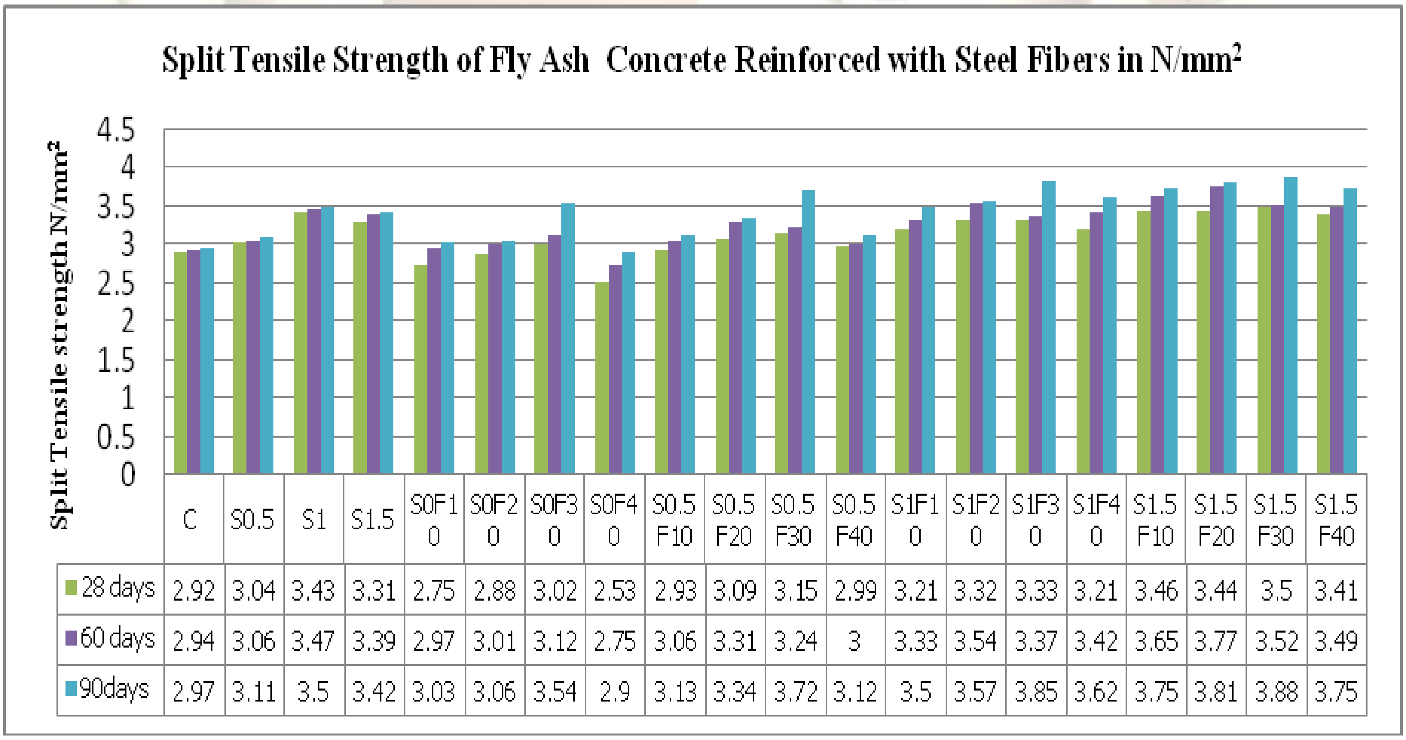
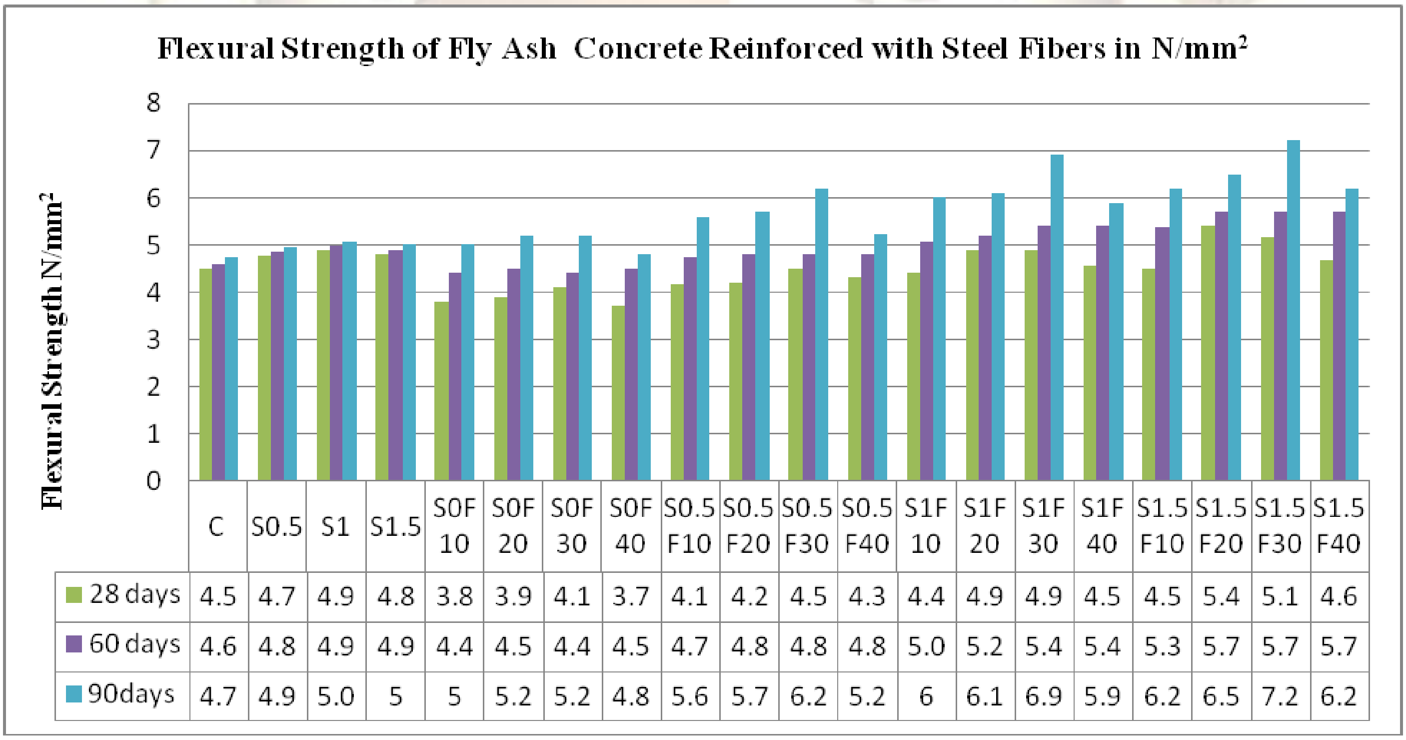


Table No.5 Flexural strength results

Sl. No.	Mix No.	Steel fiber %	Fly ash %	Flexural strength N/mm^2			Comparison of % Improvement of flyash fiber reinforced concrete		
				28 days	60 days	90 days	28 days	60 days	90 days
1	C	0 %	0 %	4.5	4.6	4.74	0	0	0
2	S0.5	0.5 %	0 %	4.76	4.86	4.95	5.77	5.65	4.43
3	S1	1 %	0 %	4.9	4.98	5.08	8.88	8.26	7.17
4	S1.5	1.5 %	0 %	4.8	4.9	5	6.66	6.52	5.48
5	S0F10	0 %	10 %	3.8	4.4	5	-15.55	-4.34	5.48
6	S0F20	0%	20 %	3.9	4.5	5.2	-13.33	-2.17	9.70
7	S0F30	0%	30%	4.1	4.4	5.2	-8.88	-4.34	9.70
8	S0F40	0%	40%	3.7	4.5	4.8	-17.77	-2.17	1.26
9	S0.5F10	0.5 %	10 %	4.17	4.74	5.6	-7.33	3.04	18.14
10	S0.5F20	0.5 %	20 %	4.2	4.8	5.7	-6.66	4.34	20.25
11	S0.5F30	0.5 %	30%	4.5	4.8	6.2	0	4.34	30.80
12	S0.5F40	0.5 %	40%	4.31	4.8	5.23	-4.22	4.34	10.33
13	S1F10	1%	10%	4.41	5.08	6	-2	10.43	26.58
14	S1F20	1%	20%	4.9	5.2	6.1	8.88	13.04	28.69
15	S1F30	1%	30%	4.9	5.4	6.9	8.82	17.39	45.56
16	S1F40	1%	40%	4.57	5.4	5.9	1.55	17.39	24.47
17	S1.5F10	1.5%	10%	4.5	5.36	6.2	0	16.52	30.80
18	S1.5F20	1.5%	20%	5.4	5.7	6.5	20	23.91	37.13
19	S1.5F30	1.5%	30%	5.17	5.7	7.2	14.88	23.91	51.89
20	S1.5F40	1.5%	40%	4.68	5.7	6.2	4	23.91	30.80

Fig No.7 Flexural strength of Fly ash Concrete Reinforced with steel fibers



$$\text{Percentage Comparison} = \frac{[\text{Strength of flyash fiber reinforced concrete - Strength of control concrete}]}{[\text{Strength of control concrete}]} \times 100$$

IV. CONCLUSIONS

Based on the experimental results, it was found that the amount of steel fibers which can be added to the concrete for improving its strength characteristics may be 1% by weight. Addition of steel fibers more than 1% generally affects the Compressive strength, Split tensile strength and Flexural strength of the concrete. The optimum steel fiber may be added to the concrete without flyash may be taken as 1%. It was found that the partial replacement of cement by fly ash at 30% replacement level increased the compressive, split tensile and flexural strength in fly ash concrete than 10%, 20% and 40% replacement level. The optimum steel fiber may be added to the concrete with flyash may be taken as 1.5%. It is concluded that cement in concrete can be replaced upto 30% by flyash with incorporation of steel fibers upto 1.5% to improve its strength characteristics.

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