International Journal of Research in Advent Technology, Vol.2, No.3, March 2014
E-ISSN: 2321-9637

EFFECT OF STEEL AND POLYPROPYLENE FIBRES ON STRENGTH CHARACTERISTICS OF FLY ASH CONCRETE

Dhillon, Ramandeep[1], Sharma, Shruti[2] and Kaur, Gurbir[3]
[1,]*Assistant Professor, Civil Engineering Department, GZS PTU CAMPUS, Bathinda, India-151001*
[2,3]*Assistant Professor, Civil Engineering Department, Thapar University, Patiala, India-147004*

Abstract Experimental investigation has been carried out to study the effect of the fly ash content with steel and polypropylene fibres on the properties of fly ash concrete. Cement has been replaced with 15, 20 and 25 per cent fly ash by mass. Two types of fibres, steel as well as polypropylene fibres have been used in percentages of 0.5% and 1.0% by volume. Effect of varying percentages of steel and polypropylene fibres on the compressive strength, split tensile strength and flexural strength of fly ash concrete has been studied. Test results indicate with the increase in percentage of fly ash content, the compressive strength, split tensile strength and flexural strength of concrete decreases but this decrease is compensated by the use of fibres in concrete. Steel fibres give better results than polypropylene fibres. Also with the percentage increase in fibre contents, more increase in all strengths is observed.

Keywords: Fly Ash, Steel fibres, polypropylene fibres, Compressive Strength, Flexure Strength, Tensile Strength.

1. INTRODUCTION

The focus of the current research is to enhance the concept of use of steel and polypropylene fibres in Fly ash Concrete to increase the concrete ductility and its strength, as well as to improve overall durability. The fibres are randomly dispersed throughout the concrete matrix providing for better distribution of both internal and external stresses by using a three dimensional reinforcing network. Effect of both steel and polypropylene fibres on the mechanical properties of Fly ash concrete is investigated in this study.

The primary role of the fibres in hardened concrete is to modify the cracking mechanism. By modifying the cracking mechanism, the macro cracking becomes micro cracking. The cracks are smaller in width, thus reducing the permeability of concrete and the ultimate cracking strain of the concrete is enhanced. The fibres are capable of carrying a load across the crack. The weak matrix in concrete, when reinforced with fibres, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete. Because of the vast improvements achieved by the addition of fibres to concrete, there are several applications where Fibres Reinforced Concrete (FRC) can be intelligently and beneficially used. The principal fibres in common commercial use for Civil Engineering application includes glass, polypropylene and carbon fibres. The study investigates the effect of polypropylene as well as steel fibres in varying proportions on the properties of fly ash concrete namely compressive strength, flexural strength and split tensile strength.

2. Experimental program

2.1 Materials

Ordinary Portland cement of grade – 43 (Ultra tech cement) conforming to Indian standard IS: 8112-1989 has been used in the present study, Fly ash (specific gravity= 2.14 to 2.42) used has been obtained from Lehra Mohobbat thermal power plant, District Bathinda. The sand (fineness modulus = 2.50) used was locally procured and conformed to grading zone III. Sieve Analysis of the Fine Aggregate was carried out in the laboratory as per IS 383-1970 and potable water. The broken stone is generally used as a coarse aggregate (fineness modulus = 7.68). The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 20 mm was used. The physical properties of coarse aggregates used are provided in **Table 1**. Two types of fibres are used

(i) Steel fibre and
(ii) Polypropylene fibres

Steel fibres are of length 35mm and average thickness of 0.75 mm i.e. having aspect ratio 50. Polypropylene fibre used is Recron 3s fibre (CT-2024)

2.2 Mix proportions

M25 concrete mix was designed using IS 10262:2009. To achieve the required workability of concrete mix, water reducing admixture i.e. superplasticizer, namely Sikavisco Crete-SC001 is added to the matrix at a desired dosage rate. In concrete batching, first the natural coarse aggregates are added in the mixer, subsequently, fine aggregates and cement are added to the mixer the ingredients are dry mixed in the mixer for 2 minutes. Then half of water is added and again mixed for 1 minute. After this, the rest of the water along with the quantity of required superplasticizer is added and mixed for another 2 minutes. The mixture is now ready to be poured in the moulds.

2.3 Specimen Details

150mm cube is used to study the compressive strength of various mixes. The cubes are filled with fresh concrete using vibrating table. Immediately after casting cubes, the specimens are covered with gunny bags to prevent water evaporation. Three cubes are casted for each parameter. The compressive strength test is carried out for 7 days and 28 days.

The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete. The test consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens. The ratio of the split tensile strength to cylinder strength not only varies with the grade of the concrete but is also dependent on the age of concrete. This ratio is found to decrease with time after about a month. The air-cured concrete gives lower tensile strength than that given by moist-cured concrete

The flexural strength test of beam, a specimen of size 700*150*150mm is placed over two point loading arrangement and the stresses produced during breakage of specimen. The flexural strength is reported as Modulus of Rupture

The experimental program consists of investigating compressive strength, split tensile strength and flexural strength of fly ash concrete modified by the use of steel and polypropylene fibers. Cement was replaced with 15%, 20% and 25% of fly ash in concrete. Fly ash concrete was then further modified by using steel and polypropylene fibers in two proportions of 0.5% and 1.0%. The specimens have been classified as control (PC), which denotes the plain concrete, steel fibres (SF) and polypropylene fibres (PPF) followed by percentage addition of volume fraction. Experiments programs and Test matrix are outlined in a flow chart in **Figure 1**. Nomenclatures for SF and PPF are enlisted in **Tables 2 and 3**respectively.The proportions of various constituents of concrete of all mixes i.e. for cube, beam and cylinder specimen has been detailed in Tables 4-6.

3. Result and Discussion

Experimental results summarized in Table 7, represent effect of steel fibres on f_{ck}, f_{sp} and ft, and Table 8 represent the effect of polypropylene fibres on all three strength properties, where f_{ck} is compressive strength, f_{sp} is split tensile strength and ft flexure strength.

3.1 Compressive Strength

3.1.1 Effect of steel fibre

Figure 2 and 3 represent 7 and 28 days compressive strength results respectively. Both 7 days as well as 28 days compressive strength of fly ash concrete modified by steel fibres is higher than plain concrete irrespective of percentage of fly ash. When the percentage of fly ash increases from 15% to 25%, increase in strength of concrete modified by the addition of steel fibres reduces. At 7 days compressive strength, as the percentage of fly ash increases the strength of concrete containing steel fibres decreases. The percentage increase in strength with 15% fly ash is more when fibre content is increased from 0.5% to 1.0% while the least percentage increase is observed in case of 25% fly ash. When the fibre content increases from 0.5% to 1.0%, the percentage improvement is 35.93, 34.67 and 20.43 in case of 15%, 20% and 25% fly ash replacement respectively. At 28 days compressive strength, with the increase in fibre content from 0.5% to 1.0%, the percentage improvement in strength with respect to plain concrete is 58.72, 46.76 and37.83 in case of 15%, 20% and 25% fly ash replacement respectively

3.1.2 Effect of polypropylene fibre

The effect of polypropylene fibre on compressive strength of concrete at 7 and 28 days have been graphically represented in Figure 4 and 5respectively.Both 7 days as well as 28 days compressive strength of fly ash concrete modified by polypropylene fibres is higher than plain concrete irrespective of percentage of fly ash. When the percentage of fly ash increases from 15% to 25%, increase in strength of concrete modified by the addition of polypropylene fibres reduces. At 7 days compressive strength and fibre content of 0.5% volume fraction and cement replacement with fly ash by 15%, 20% and 25% ratios, the percentage improvement in strength is of the order 19.37, 4.51 and 1.98 respectively. For same fly ash replacement ratio, when fibre is added at 1.0% volume fraction, the percentage improvement in strength is of the order 35.96, 22.87 and 4.42 respectively. At 28 days compressive strength with 0.5% fibre dosage with the replacement of fly ash as 15%, 20% and 25%, the percentage improvement in strength is 1.62, 9.12 and 1.01 respectively. For 1.0% fibre dosage and same fly ash replacement ratios, the percentage improvement is of the order 9.78, 10.51 and 4.29 respectively.

3.2 Split Tensile Strength

The effects of steel fibres on split strength of concrete at 28 days are graphically represented in Figure 6. The 0.5% dosage of fibre with three replacement ratios of fly ash the percentage improvement in cylindrical strength at 28 days comes out to be 30.09, 50.77 and 43.65 respectively. For 1.0% addition of fibres and with similar fly ash replacement ratios, the percentage improvement in strength is 39.87, 51.16 and 49.02 respectively. With the percentage increment of fly ash, split tensile strength decreases but when with the

3.2.1 Effect of steel fibre

split tensile strength of plain concrete at 28 days comes out to be 5.46 MPa. For

same fly ash content if fibre addition is increased from 0.5% to 1.0%, the strength increases. More improvement is seen in case of 20% fly ash with 1% steel fibre while the least is seen in case of 25% fly ash and 0.5% steel fibre.

3.2.2 Effect of polypropylene fibre

The effects of polypropylene fibres on split strength of concrete at 28 days are graphical represented in Figure 7. The cylindrical strength of plain concrete at 28 days is 6.42 MPa. For 0.50% addition of PPF and with the replacement of cement by 15%, 20% and 25% with fly ash, the percentage improvement comes out to be 5.17, 12.77 and 1.83 respectively. For 1.0% fibre addition and with same fly ash replacement ratio, the percentage improvement is 17.48, 23.02 and 19.55 respectively. With the percentage increment of fly ash, split tensile strength decreases but when with the same fly ash content if fibre addition is increased from 0.5% to 1.0%, the strength increases. More improvement is seen in case of 20% fly ash with 1% polypropylene fibre while the least is seen in case of 25% fly ash and 0.5% polypropylene fibre

3.3 Flexure strength

3.3.1 Effect of steel fibres

The effects of steel fibres on flexural strength of concrete at 28 days are graphical represented in Figure 8. The flexural strength of plain concrete at 28 days is 7.48 MPa. For 0.5% fibre addition with 15%, 20% and 25% fly ash replacement, the percentage improvement is of the order 30.68, 40.82 and 12.62 respectively. For 1.0% fibre addition with same replacement of fly ash, the percentage improvement is of the order 32.79, 48.13 and 44.91 respectively. With the percentage increment of fly ash, split tensile strength decreases but when with the same fly ash content if fibre addition is increased from 0.5% to 1.0%, the strength increases. More improvement is seen in case of 20% fly ash with 1%

steel fibre while the least is seen in case of 25% fly ash and 0.5% steel fibre

3.3.2 Effect of polypropylene fibre

The effects of polypropylene fibres on flexural strength of concrete at 28 days are graphical represented in Figure 9.The flexural strength of plain concrete is 7.48 MPa. For 0.5% fibre addition and with the replacement of fly ash as 15%, 20% and 25% with the weight of cement, the percentage improvement comes out to be 14.70, 3.10 and 5.55 respectively. For 1.0% fibre addition and with the same replacement of fly ash, the percentage improvement is 23.75, 26.81 and 7.43. With the percentage increment of fly ash, split tensile strength decreases but when with the same fly ash content if fibre addition is increased from 0.5% to 1.0%, the strength increases. More improvement is seen in case of 20% fly ash with 1% polypropylene fibre while the least is seen in case of 25% fly ash and 0.5% fibre for the same case.

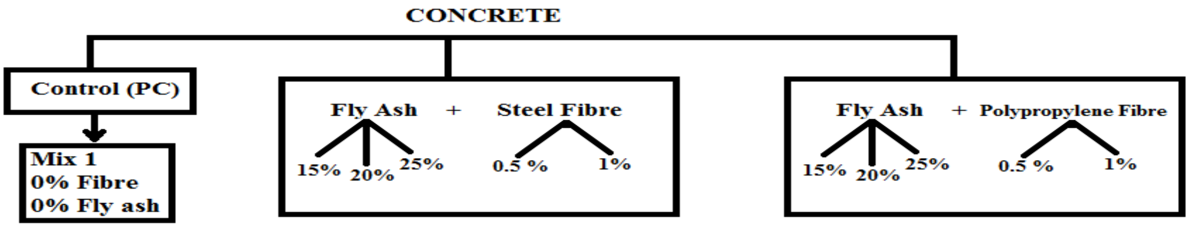

Figure 1: Flow chart of experimental program

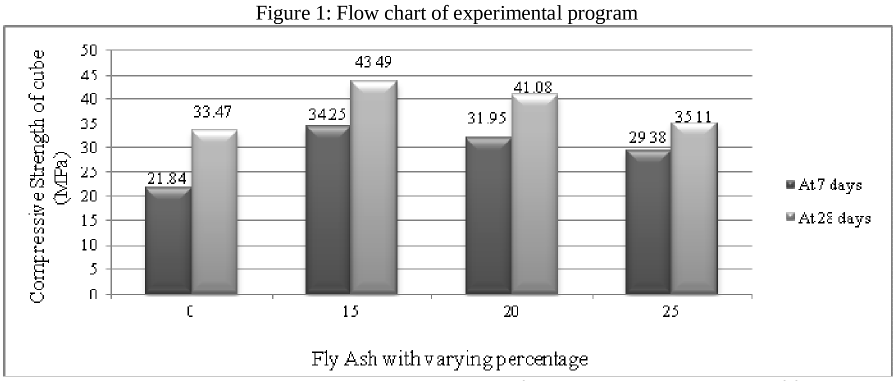

Figure 2. 7 and 28 days compressive strength using 1% steel fibre with varying percentage of fly ash

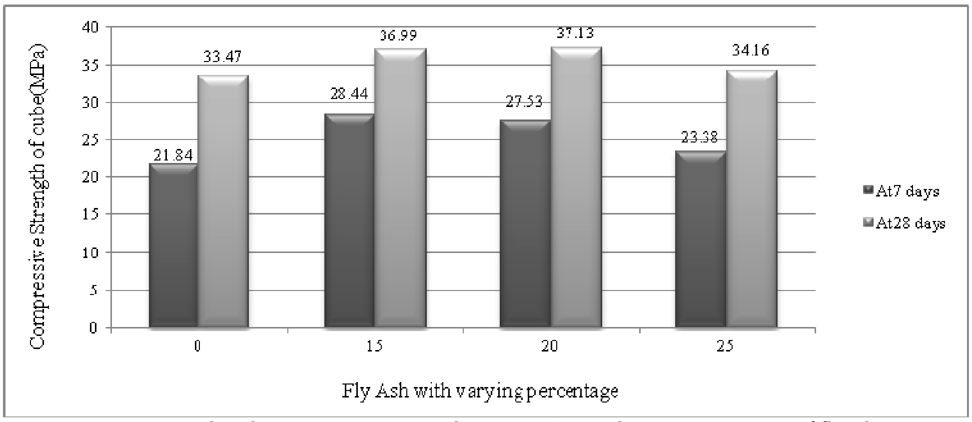

Figure 3.7 and 28 days compressive strength using 0.5%SF with varying percentage of fly ash

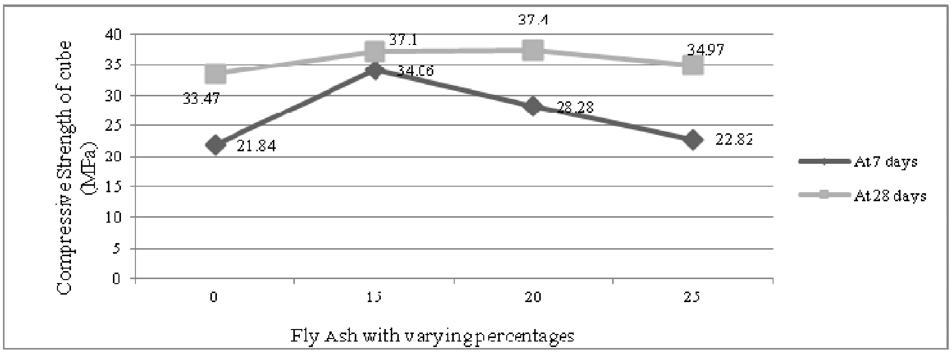

Figure 4.7 and 28 days compressive strength using 1% PPF with varying percentages of fly ash.

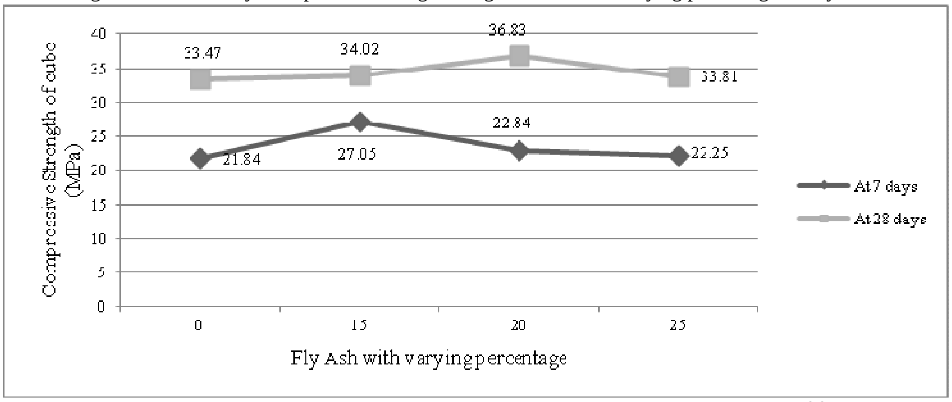

Figure 5.7 and 28 days compressive strength using 0.5%PPF with varying percentages of fly ash.

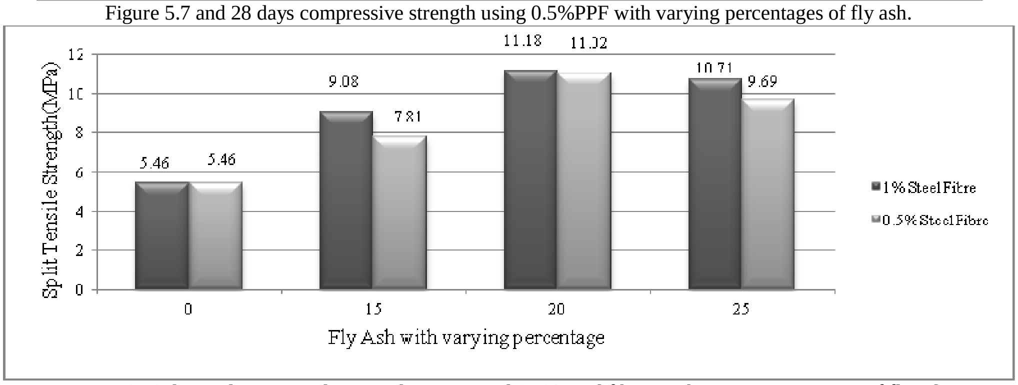

Figure 6.28 days splitting tensile strength using 1 and 0.5% steel fibres with varying percentage of fly ash.

Characteristics	Type	Specific Gravity	Water absorption	Fineness Modulus	Maximum Size

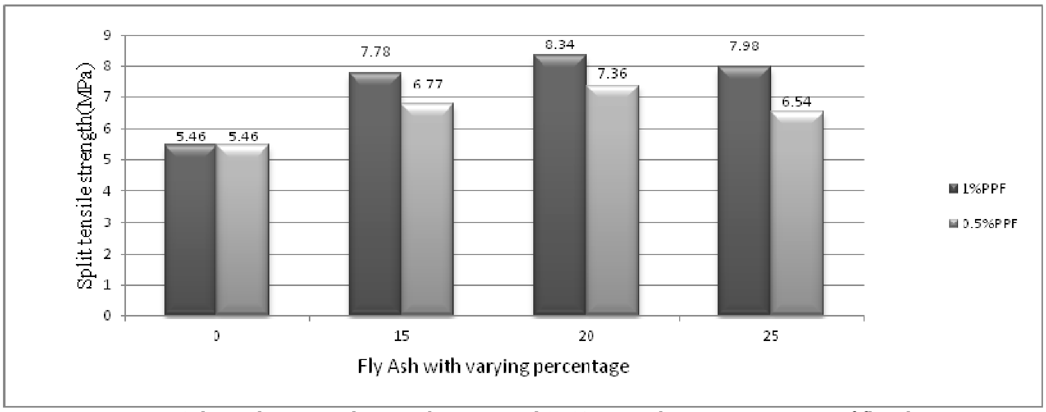

Fig 7.28 days splitting tensile strength using 1 and 0.5% PPF with varying percentage of fly ash.

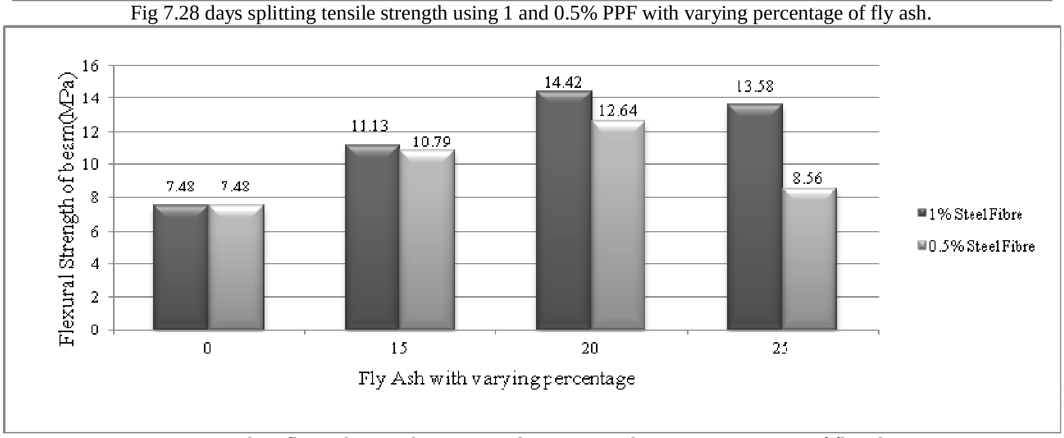

Fig 8.28 days flexural strength using 1 and 0.5% SF with varying percentage of fly ash.

Figure 9. 28 days flexural strength using 1 and 0.5% PPF with varying percentage of fly ash.

Value	Crushed	2.61	2.37%	7.68	20mm

Table1. Properties of Coarse aggregate

Table 2. Nomenclature of steel fibres for various mixes

No. of Mixes	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix7
Nomenclature	FC 15 SF 0.5	FC 15 SF 1.0	FC 20 SF 0.5	FC 20 SF 1.0	FC 25 SF 0.5	FC 25 SF 1.0

Table 3: Nomenclature of PPF for various mixes

No. of Mixes	Mix 8	Mix 9	Mix 10	Mix 11	Mix 12
Nomenclature	FC 15 PPF 0.5	FC 15 PPF 1.0	FC 20 PPF 0.5	FC 20 PPF 1.0	FC 25 PPF 0.5

Table 4. Mix proportion for one cube specimen (Kg)

~~Mixes~~	~~FC~~	~~Fibre(gm)~~	~~Cement~~	~~Sand~~	~~NA~~	~~Water(lt)~~	~~Superplasticizer~~
~~Mix 1~~	~~0~~	~~0~~	~~1.53~~	~~2.0~~	~~4.45~~	~~0.68~~	~~0~~
Mix 2/8	0.23	7.65	1.30	2.0	4.45	0.68	24.90
Mix 4/10	0.31	7.70	1.23	2.0	4.45	0.68	20.08
Mix 6/12	0.38	7.65	1.15	2.0	4.45	0.68	20.70
Mix 3/9	0.23	15.3	1.30	2.0	4.45	0.68	24.90
Mix 5/11	0.31	15.4	1.23	2.0	4.45	0.68	22.08
Mix 7/13	0.38	15.3	1.15	2.0	4.45	0.68	20.70

~~Table 5. Mix proportion for one cylinder specimen (Kg)~~

Mixes	FC	Fibre (gms)	Cement	Sand	NA	Water (lt)	Superplasticizer
~~Mix 1~~	~~0~~	~~0~~	~~2.41~~	~~3.14~~	~~7.0~~	~~1.07~~	~~0~~
Mix 2/8	0.36	12	2.04	3.14	7.0	1.07	6.72
Mix 4/10	0.48	12	1.92	3.14	7.0	1.07	5.76
Mix 6/12	0.60	12	1.80	3.14	7.0	1.07	5.42
Mix 3/9	0.36	24	2.04	3.14	7.0	1.07	6.12
Mix 5/11	0.48	24	1.92	3.14	7.0	1.07	5.72
Mix 7/13	0.60	24	1.80	3.14	7.0	1.07	5.42

Table 6. Mix proportion for one beam specimen (Kg)

Mixes	FC	Fibre (gms)	Cement	Sand	NA	Water (lt)	Superplasticizer
~~Mix 1~~	~~0~~	~~0~~	~~7.15~~	~~9.25~~	~~20.79~~	~~3.22~~	~~0~~
Mix 2/8	1.08	35.78	6.08	9.25	20.79	3.22	18.24
Mix 4/10	1.43	35.75	5.72	9.25	20.79	3.22	17.16
Mix 6/12	1.79	35.75	5.36	9.25	20.79	3.22	16.08
Mix 3/9	1.08	71.57	6.08	9.25	20.79	3.22	18.24
Mix 5/11	1.43	71.50	5.12	9.25	20.79	3.22	17.16
Mix 7/13	1.79	71.50	5.36	9.25	20.79	3.22	16.08

Table 7.Test results for f_{ck}, f_{sp} and f_t (when steel fibres are used)

Type of Mixes	f_{ck}		fsp	ft
	7days	28days		
Mix 1	21.84	33.47	5.46	7.48
Mix 2	28.44	36.99	7.81	10.79
Mix 3	34.25	43.49	9.08	11.13
Mix 4	27.53	37.13	11.09	12.64
Mix 5	31.95	41.08	11.08	14.42
Mix 6	23.38	34.16	9.69	8.56
Mix 7	29.38	35.11	10.71	13.58

Table 8.Test results for f_{ck}, f_{sp} and f_t (when polypropylene fibres are used)

Type of Mixes	f_{ck}		fsp	ft
	7days	28days		
Mix 1	21.84	33.47	6.42	7.48
Mix 8	27.05	34.02	6.77	8.77
Mix 9	34.06	37.10	7.78	9.81
Mix 10	22.84	36.83	7.36	7.22
Mix 11	28.28	37.40	8.34	10.22
Mix 12	22.25	33.81	6.54	7.92
Mix 13	22.82	34.97	7.98	8.08

4.0 Conclusionss

The conclusions derived from the investigations can be summarized as following :

- The replacement of cement withflyash by mass in percentage (15, 20 and 25 per cent) decreases the compressive strength, split tensile strength and flexural strength as replacement percentage increases.
- The addition of steel fibres to flyash concrete by volume (0.5 and 1 per cent) increases the compressive strength of flyash concrete at both 7 and 28 days. Similar is the case with split tensile strength of cylinder and flexural strength of beam. Maximum improvement is observed when 15% of FA is replaced with cement and 1% of SF is added to it. While in case of split tensile strength and flexural strength, maximum improvement is seen in case of 20%FA replaced with cement and 1% SF is added to it. But in all the above cases, least improvement is seen is in 25%FA replacement along with the addition of 0.5% SF.
- Observing the failure pattern of specimen, it is observed that the addition of steel fibres increases the ductility of flyash concrete.
- Polypropylene fibre addition improves the compressive, split tensile and flexural strength of concrete than plain concrete. But its improvement is less as compared to that of steel fibre for the same case.
- Drastic improvement in strength properties is observed in the case of 15% and 20% fly ash replacement along with addition of fibres while the least improvement is seen in the case of

25% fly ash replacement with fibre addition.

- Water reducing admixture such as superplasticizer is required for workable mix as steel fibre percentage increases.

Scope of future work

- Durability investigations on fly ash concrete modified with steel as well as polypropylene.
- Only the effect of 0.5% and 1.0% steel and polypropylene fibres were investigated in the study. The percentage replacements can be further varied to study their effect on properties of fly ash concrete.
- Effect of addition of other types of fibres like san fibre, bamboo fibre etc. can be investigated in fly ash concrete.
- Effect of strength and durability of fly ash concrete using different types of steel fibres with variable shapes and aspect ratio can also be investigated

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