Study Of Mechanical Properties Of M 25 Grade Steel Fiber Reinforced Concrete Made With Fly Ash

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Abstract- *Steel Fibre Reinforcement Concrete (SFRC), a composite material made of cements, water, fine and coarse aggregate and dispersion of discontinues small fibres (steel fibre) is well as one of the superior crack resisting building materials. The primary function of steel fibre is to modify micro and macro cracking by intercepting cracks at their origin and inhibit crack growth. As a result of this ability to arrest cracks, fibre composite possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading; and the fibres are able to hold the matrix together even after extensive cracking.*

This paper deals with Investigation for M 25 grade of concrete to study the Compressive, Split Tensile and Flexural strength of steel fibre reinforced concrete (SFRC) containing fibers of an interval of 0.25% from 0.0% to 0.75% volume fraction of hook end Steel fibers were used. The percentage of Fly Ash by weight is to be increased by 10% from 00% to 30%. After curing these specimen were tested as per relevant codes of practice Bureau of Indian Standard. A result data obtained has been analysed and compared with a control specimen. A relationship between Compressive strength vs. days, Split tensile strength vs. days and Flexural strength vs. days represented graphically.

Keywords- Steel Fibers, Fly Ash, Compressive Strength, Split Tensile Strength and Flexural Strength

I. INTRODUCTION

1.1 STEEL FIBERS

The advantages of using fibres as reinforcement have been known since ancient times; e.g. 3500 years ago, sun-baked bricks were reinforced with straw. In modern times, in the early 1900s, asbestos cement was the first widely used manufactured composite.

In the 1960s, research on fibre-reinforced concrete was already advancing fast, and at the present time, fibres of various kinds are used to reinforce concrete in structural applications. Due to its high stiffness, the steel fibre is probably the most commonly used fibre material. However, synthetic fibres are gaining ground, and new materials are under continuous development.

Various industries produce numerous solid waste materials. The disposal of these solid waste materials is an environment hazard for the surrounding living beings. Now a day's increasing environmental concerns and sustainable issues, the utilization of solid waste materials is the need of the hour. The productive use of solid waste materials is the best way to alleviate the problems associated with their disposal. The construction industry has enormous potential for the use of solid waste materials as construction material. Based upon their properties, the solid waste materials can either be used as supplementary cementitious materials or as replacement of fine/coarse aggregate in concrete or mortars. Based on the research reports some solid waste materials such as fly ash, silica fume, grounded blast furnace slag etc have been put in use in manufacturing of either cement or concrete.

As per ASTM C 618-89, pozzolana is defined as "siliceous or siliceous and aluminous materials which in themselves possess little or no cementitious value but will in finely divided form and in the presence of moisture chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties". There are pozzolana which differ from the specific definition in that they do possess significant cementitious values.

II. LITERATURE REVIEW

Vairagade and Kene (2013) investigated the compressive strength of SFRC using hooked-end steel fibre and copper coated crimped round steel fibres of different aspect ratios for a with fibre dosage of 0.5%. It was found that compressive strength increased to a maximum tune of about 10.51%. Each type of steel fibres enhanced the compressive strength.

Campello et al. (2014) studied the effect of short metallic fibres on behavior of cement mortar. Plain steel fibres of length 25 mm and aspect ratio of 109 were used with fibre dosages of 0.7%, 1.4% and 2.0%. Compressive strength of cement mortar was increased by 22.2% and 26% for the fibre dosages of 0.7% and 1.4% respectively. However, the growth in compressive strength was dropped to 17.7% when the fibre dosage was increased to 2.0%.

Jian-he et al. (2014) studied the flexural strength of a new SFRC blended with crumb rubber and recycled aggregate. Steel fibre dosage of 1% was used in the study. Shear-wave type steel fibres with a length of 32 mm were used in the study. Coarse aggregate was replaced by recycled aggregate and the crumb rubber was used in the range of 0% to 16%. A reduction in the flexural strength by 8.2% was reported in the presence of steel fibres and the absence of crumb rubber.

Khaloo et al. (2014) evaluated the effect of steel fibres on compressive strength of Self-Compacting Concrete (SCC). The study included two mix designs with strengths of 40 MPa and 60 MPa and fibre dosages of 0.5%, 1%, 1.5% and 2%. Straight steel fibres of length 20.6 mm and aspect ratio 20 were used. Increase in fibre dosage resulted decrease in compressive strength in the range of 9-24%.

Saidani et al. (2016) conducted experiments on understanding influence of different types of PP fibres on the compressive strength of concrete. It was concluded that the addition of fibres slightly affected the compressive strength of concrete.

Karahan and Atis (2011) and Hsie et al. (2008) concluded that the PP fibres are effective in reducing the drying shrinkage of concrete.

Zhang and Li (2013) studied the influence of PP fibres on water impermeability property of fly ash and silica fume blended concrete. Decrease in length of water permeability was observed in the presence of PP fibres.

III. EXPERIMENTAL PROGRAMME

3.1 Materials

Constituent materials used to make concrete can have a significant influence on the properties of the concrete. The following sections discuss constituent materials used for manufacturing of both conventional concrete (CC) and Fly Ash based Fiber Reinforced Concrete (FFRC). Chemical and physical properties of the constituent materials are presented in this section.

3.1.1 Cement

Ordinary Portland Cement 53 grade was used corresponding to IS 12269 (1987). The physical properties of the cement as obtained by the manufacturer are presented in the Table 3.1.

Table 3.1 Physical Properties of Cement

Physical properties	Test result
Specific gravity	3.15
Fineness (m^2/Kg)	311.5
Normal consistency	30%
Initial setting time (min)	90
Final setting time (min)	220
Soundness Lechatelier Expansion (mm) Autoclave Expansion (%)	 0.8 0.01
Compressive strength (MPa) 3 days 7 days 28 days	 25 39 57

3.1.2 Fly Ash

The physical properties of the Fly Ash as obtained by the manufacturer are presented in the Table 3.2.

Table 3.2 Physical properties of Fly Ash

Material	Specific gravity	Fineness (m^2/kg)	Water absorption (%)
Fly Ash	2.2	360	40-60

3.1.3 Coarse aggregate

Crushed granite stones of size 20 mm used as coarse aggregate. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate 20 mm per IS 2386 (Part III, 1963) are 2.6 and 0.3% respectively. The bulk density, impact strength and crushing strength values of 20 mm aggregate are 1580 kg/m3, 17.9% and 22.8% respectively.

3.1.4 Fine aggregate

Natural river sand is used as fine aggregate. The bulk specific gravity in oven dry condition and water absorption of the sand as per IS 2386 (Part III, 1963) are 2.6 and 1% respectively. Fineness modulus of sand is 2.26.

3.1.5 Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. When it is suspected that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. Water from such sources should be avoided.

3.1.6 Fibers

The steel fiber is procured from precision Drawell Pvt. Ltd., Nagpur. The steel fiber used in the study is the hook ended type HK0750 having aspect ratios 71. The constant dosages of 0.25 % fibers up to 0.75% are used by total volume of concrete. The length of dividing fiber is 50 mm and the diameter of fiber is 0.7 mm.

3.2 Test Methods

This section describes the test methods that are used for testing the hardened properties of concrete.

3.2.1 Compressive strength test

Compressive strength test was conducted on the cubical specimens for all the mixes at different curing periods as per IS 516 (1991) shown in fig 3.1. Three cubical specimens of size 150 mm x 150 mm were cast and tested for each age and each mix. The compressive strength (f'c) of the specimen was calculated by dividing the maximum load applied to the specimen by the cross-sectional area of the specimen.

Fig.3.1 compressive strength of cubes

3.2.2 Split Tensile Strength

Splitting tensile strength (STS) test was conducted on the specimens for all the mixes at different curing periods as per IS 5816 (1999). Three cylindrical specimens of size 150 mm x 300 mm were cast and tested for each age and each mix. The load was applied gradually till the failure of the specimen occurs. The maximum load applied was then noted. Length and cross-section of the specimen was measured. The splitting tensile strength (f_{ct}) was calculated as follows:

$$f_{ct} = 2P/ (\Pi\, l\, d)$$

Where, f_{ct} = Splitting tensile strength of concrete (N/mm^2)
P = Maximum load applied to the specimen (in Newton)
l = Length of the specimen (in mm)
d = cross-sectional diameter of the specimen (in mm)

Fig.3.2Split Tensile Strength of Cubes

3.2.3 Flexural Strength

Flexural strength test was conducted on the specimens for all the mixes at different curing periods as per IS 516 (1991). Three concrete beam specimens of size 100 mm x 100 mm x 500 mm were cast and tested for each age and each mix. The load was applied gradually till the failure of the specimen occurs. The maximum load applied was then noted. The distance between the line of fracture and the near support '*a*' was measured. The flexural strength (f_{cr}) was calculated as follows:

When '*a*' is greater than 13.3 cm for 10 cm specimen, f_{cr} is

$$f_{cr} = (P \times l) / (\mathrm{b} \times d^2)$$

When '*a*' is less than 13.3 cm but greater than 11.0 cm for 10 cm specimen, f_{cr} is

$$f_{cr} = (3 \times P \times a) / (b \times d^2)$$

Where, f_{cr} = Flexural strength of concrete (N/mm^2)
P = Maximum load applied to the specimen (in Newton)
b = measured width of the specimen (in mm)
d = measured depth of the specimen at the point of failure (in mm)

l = Length of the specimen on which the specimen was supported (in mm)

Fig.3.3 Flexural Strength of Cubes

3.3 Mix Design

Table 3.4Mix Proportions of CC & FFRC

Mix Type	Fly Ash (%)	Steel Fibers (%)	Cement Kg/m^3	Fly Ash Kg/m^3	Water l/m^3	20mm kg/m^3	Sand kg/m^3	Fibers Kg/m^3
CC	0	0	384	0	202	1139	636	0
FFRC_0.25&10	10	0.25	345.6	26.82	202	1139	636	19.62
FFRC_0.25&20	20	0.25	307.19	53.64	202	1139	636	19.62
FFRC_0.25&30	30	0.25	268.79	80.45	202	1139	636	19.62
FFRC_0.50&10	10	0.50	345.6	26.82	202	1139	636	39.25
FFRC_0.50&20	20	0.50	307.19	53.64	202	1139	636	39.25
FFRC_0.50&30	30	0.50	268.79	80.45	202	1139	636	39.25
FFRC_0.75&10	10	0.75	345.6	26.82	202	1139	636	58.87
FFRC_0.75&20	20	0.75	307.19	53.64	202	1139	636	58.87
FFRC_0.75&30	30	0.75	268.79	80.45	202	1139	636	58.87

This section describes the proportions of M 25 grade conventional concrete mix proportions as per IS 10262 (2009) and IS 456 (2000) shown in Table 3.4.

IV. RESULTS AND DISCUSSIONS

4.1 Introduction

In this Chapter, the test results are presented and discussed. The test results cover the performance of Conventional Concrete (CC) and Fly Ash blended Fiber Reinforced Concrete (FFRC) at different replacement levels of steel (0.25%, 0.5% and 0.75%) and Fly Ash (10%, 20% and 30%). The hardened properties of CC and FFRC viz. compressive strength, split tensile strength and flexural strength were determined at different curing periods (14, 28 and 56 days).

4.2 Variations in Compressive Strength

The variations in compressive strength values of CC and FFRC at different curing periods are shown in Table 4.1 and Fig 4.1.

From the results it is seen that the concrete mixes with partial replacement of Fly Ash (FA) in cement and Steel Fibers in total volume have attained lower values of compressive strength at initial period (14 days) as compared to that of conventional concrete (CC) as shown in Fig.4.1.

It is mainly due to the use of class F fly ash replacement in the cement and attributed to the slower pozzolanic action of fly ash that decreases the Compressive strength at early ages (Liu, 2010).

But there was significant improvement observed in the compressive strength of FFRC after 28 days and 56 days of curing as shown in Fig. 4.1, FFRC has attained higher value of compressive strength than that of CC as shown in Table 4.1 and Fig. 4.1. Studies already revealed that mechanical properties of fly ash concrete continued to increase with age (Siddique, 2003; Siddique, 2011; Liu, 2010).

From the table 4.1, the compressive strength of FFRC with different volumes of fibers and Fly Ash at the age of 28 days and 56 days, it is clearly shown that FFRC_0.25&20 has higher compressive strength and FFRC_0.75&30 has lower values of compressive strength.

Table 4.1 compressive strength of concrete mixes

Mix Type	Compressive Strength (MPa)		
	14 days	28 days	56 days
CC	22.84	33.76	36.39
FFRC_0.25&10	22.50	34.75	37.81
FFRC_0.25&20	19.90	35.85	38.32
FFRC_0.25&30	18.37	33.56	36.69
FFRC_0.50&10	21.93	32.89	36.82
FFRC_0.50&20	19.24	33.86	37.18
FFRC_0.50&30	17.49	29.24	34.17
FFRC_0.75&10	19.69	29.54	33.97
FFRC_0.75&20	16.45	24.68	28.38
FFRC_0.75&30	13.72	20.58	23.66

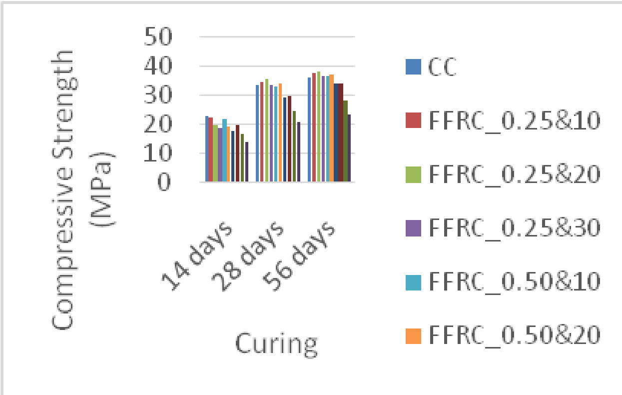

Fig 4.1 compressive strength of concrete mixes

4.3 Variations in Split Tensile Strength

The variations in split tensile strength values of CC and FFRC at different curing periods are shown in Table 4.2 and Fig 4.2.

From the results it is seen that the concrete mixes with partial replacement of Fly Ash (FA) in cement and Steel Fibers in total volume have attained lower values of split tensile strength at initial period (14 days) as compared to that of conventional concrete (CC) as shown in Fig.4.2.

It is mainly due to the use of class F fly ash replacement in the cement and attributed to the slower pozzolanic action of fly ash that decreases the split tensile strength at early ages (Liu, 2010).

But there was significant improvement observed in the split tensile strength of FFRC after 28 days and 56 days of curing as shown in Fig. 4.2, FFRC has attained higher value of split tensile strength than that of CC as shown in Table 4.2 and Fig. 4.2. Studies already revealed that mechanical properties of fly ash concrete continued to increase with age (Siddique, 2003; Siddique, 2011; Liu, 2010).

From the table 4.2, the split tensile strength of FFRC with different volumes of fibers and Fly Ash at the age of 28 days and 56 days, it is clearly shown that FFRC_0.25&20 has higher split tensile strength and FFRC_0.75&30 has lower values of split tensile strength.

Table 4.2 split strength of concrete mixes

Mix Type	Split Tensile Strength (MPa)		
	14 days	28 days	56 days
CC	2.51	3.71	4.00
FFRC_0.25&10	2.48	4.34	4.73
FFRC_0.25&20	2.19	4.48	4.79
FFRC_0.25&30	2.02	4.20	4.59
FFRC_0.50&10	2.41	4.11	4.60
FFRC_0.50&20	2.12	4.23	4.65
FFRC_0.50&30	1.92	3.66	4.27
FFRC_0.75&10	2.17	3.69	4.25
FFRC_0.75&20	1.81	3.09	3.55
FFRC_0.75&30	1.51	2.57	2.96

The variations in split tensile strength values of CC & FFRC after curing are represented in fig 4.2.

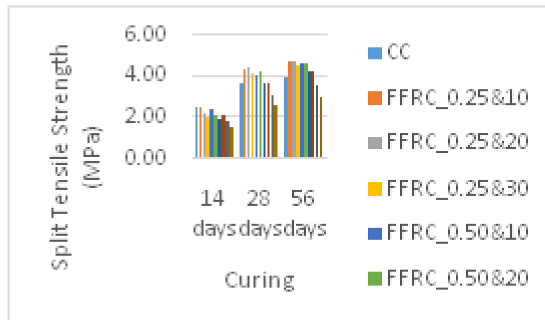

Fig. 4.2variations in split tensile strength of concrete mixes

4.4 Variations in Flexural Strength

The variations in flexural strength values of CC and FFRC at different curing periods are shown in Table 4.3 and Fig 4.3.

From the results it is seen that the concrete mixes with partial replacement of Fly Ash (FA) in cement and Steel Fibers in total volume have attained lower values of flexural strength at initial period (14 days) as compared to that of conventional concrete (CC) as shown in Fig.4.3.

Table 4.3 flexural strength of concrete mixes

Mix Type	Flexural Strength (MPa)		
	14 days	28 days	56 days
CC	3.43	5.06	5.46
FFRC_0.25&10	3.38	5.28	5.75
FFRC_0.25&20	2.99	5.45	5.82
FFRC_0.25&30	2.76	5.10	5.58
FFRC_0.50&10	3.29	5.00	5.60
FFRC_0.50&20	2.89	5.15	5.65
FFRC_0.50&30	2.62	4.44	5.19
FFRC_0.75&10	2.95	4.49	5.16
FFRC_0.75&20	2.47	3.75	4.31
FFRC_0.75&30	2.06	3.13	3.60

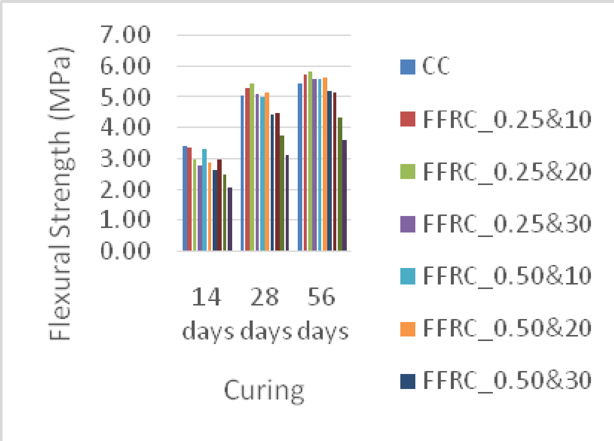

Fig. 4.3variations in flexural strength of concrete mixes

It is mainly due to the use of class F fly ash replacement in the cement and attributed to the slower pozzolanic action of fly ash that decreases the flexural strength at early ages (Liu, 2010).

From the table 4.3, the flexural strength of FFRC with different volumes of fibers and Fly Ash at the age of 28 days and 56 days, it is clearly shown that FFRC_0.25&20 has higher flexural strength and FFRC_0.75&30 has lower values of flexural strength.

The variations in flexural strength values of CC & FFRC after curing are represented in fig 4.3.

V. CONCLUSION

The following conclusions have been drawn from the present investigation.

- The concrete mixes with partial replacement of Fly Ash (FA) in cement and Steel Fibers in total volume of concrete have attained lower values of compressive strength at initial period (14 days) as compared to that of conventional concrete (CC)
- The improvement observed in the compressive strength of FFRC after 28 days and 56 days of curing, FFRC has attained higher value of compressive strength than that of CC
- It is clearly shown that FFRC_0.25&20 has higher compressive strength and FFRC_0.75&30 has lower values of compressive strength.
- The concrete mixes with partial replacement of Fly Ash (FA) in cement and Steel Fibers in total volume of concrete have attained lower values of split tensile strength at initial period (14 days) as compared to that of conventional concrete (CC)
- The improvement observed in the split tensile strength of FFRC after 28 days and 56 days of curing, FFRC has attained higher value of split tensile strength than that of CC
- It is clearly shown that FFRC_0.25&20 has higher split tensile strength and FFRC_0.75&30 has lower values of split tensile strength.
- The concrete mixes with partial replacement of Fly Ash (FA) in cement and Steel Fibers in total volume of concrete have attained lower values of flexural strength at initial period (14 days) as compared to that of conventional concrete (CC)
- The improvement observed in the flexural strength of FFRC after 28 days and 56 days of curing, FFRC has attained higher value of flexural strength than that of CC
- It is clearly shown that FFRC_0.25&20 has higher flexural strength and FFRC_0.75&30 has lower values of flexural strength.

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