Experimental Investigation On Flexural Behaviour Of Steel Fibre And Nylon Fibre Reinforced Concrete Beam

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Abstract—*Performance of Conventional concrete is enhanced by the additional of fibers in concrete. Adding a single type of fibre into concrete has limited functions, so many current researches are oriented to the development of hybrid fibre in concrete to obtain better mechanical properties. The main reason for steel and nylon fibre used in concrete matrix is to improve post cracking response of the concrete and to improve energy absorption capacity, ductility and to provide crack resistance and crack control. The introduction of concrete is brought in as a solution to develop concrete with enhanced flexural strength. In this study examines the flexural strength of concrete with two different types of fibre such as steel fibre and nylon fibre with fibre content of 0.75% of steel fibre is kept constant in each mixes and 0.50%, 0.75% of nylon fibre was varied in each mixes. The tests are to be carried out with two different grades of concrete such as M25 and M30 grade and the results are to be compared between conventional concrete to fibre reinforced concrete.*

Keywords*—*Steel Fibre, Nylon Fibre, Compression Strength, Split Tensile Strength and Flexural Strength.

I. INTRODUCTION

Concrete's versatility, durability, and economy have made it the world's most used construction material. The India uses about 7.3 million cubic meters of ready-mixed concrete each year. Engineers are continually working on it, to improve its performance with the help of innovative supplementary or replacement materials. Cement, sand and aggregate are essential needs for any construction industry. Sand is a major material used for preparation of mortar and concrete and plays a most important role in mix design. Fiber Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Incorporation of fiber in concrete has found to improve several properties like tensile strength, cracking resistance, impact and wear resistance, ductility and fatigue resistance.

This project shows the investigation on mechanical properties (compressive strength, split tensile strength, flexural strength) of Fiber Reinforced concrete. In this project I have selected two different fibers (nylon and steel fiber). Steel fiber is selected for the reasons to improve static and dynamic tensile strength, energy absorbing capacity and better fatigue strength. Nylon fiber is selected as a replacement material to increase the tensile property of concrete and also it lowest density and light weight material in the fiber.

In this research, therefore, an attempt has been made to study the feasibility of using two kinds of fibres for making FRC. The beneficial effects of non-metallic fibres like nylon 6 is to arrest the propagation of micro cracks in the plastic stage of concrete due to their lower stiffness and increased fibre availability (because of lower density as compared to steel) at a given volume fraction. It is important to have a combination of low modulus (nylon 6) and high modulus fibres (steel) to arrest the micro and macro cracks, respectively.

II. MATERIAL DETAILS

A. Cement

Ordinary Portland Cement (OPC) is by far the most important type of cement OPC 53 grade cement is mostly used for concrete production due to its higher strength. The Cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of are 12269-1987.The specific gravity was 3.122.

B. Fine Aggregate

The aggregate size is lesser than 4.75 mm is considered as fine aggregate. It was stored in open space free from dust and water. River sand of 2.36 mm size sieve passed was used as fine aggregate. The specific gravity of 2.566 and fineness modulus 3.6 was used in the investigation.

C. Coarse Aggregate

The aggregate size bigger than 4.75 mm, is considered as coarse aggregate. Coarse aggregate passing through 20 mm sieve and retained in 12.5 mm sieve is collected for concrete work. Crushed angular granite metal of 6 to 12.5 mm size from a local source was used as coarse aggregate. The specific gravity of 2.743 and fineness modulus 4.7 was used.

D. Steel Fiber

Steel fibers are used concretes are given higher flexural, tensile and compression strength when compare to conventional concrete. Steel fibers are generally used to enhance the tensile strength and ductility of concrete. The primary function of steel fibers is to modify micro and macro cracking. By intercepting cracks at their origin, the steel fibers inhibit crack growth.

In this project work **Crimped steel fibers** is used because bonding ability is higher than other types of steel fibre and it has a length 50mm and diameter 10mm. Aspect ratio of steel fiber is 50.

Steel fibers are distributed uniformly throughout the concrete matrix. The primary function of steel fibers is to modify micro and macro cracking. By intercepting cracks at their origin, the steel fibers inhibit crack growth. For this reason, SFRC can be used to replace welded wire reinforcement or rebar which is used to control temperature or shrinkage cracks. The steel fibre sample is shown in Figure 1.

Figure 1: Steel Fibre

E. Nylon Fiber

Nylon fibers are used in many applications, including clothes fabrics, bridal veils, package paper, carpets, musical strings, pipes, tents, and rope. Further, these two types of fibers can complement each other and further improve the engineering properties of concrete.

In this project work **nylon 6** fiber is used and it has a length 18mm and diameter 10 micron. The properties of nylon fibre is shown below

Tenacity-elongation at break ranges from 8.8g/d-18% to 4.3 g/d-45%. Its tensile strength is higher than that of wool, silk, rayon, or cotton.

- 100% elastic under 8% of extension
- Specific gravity of 1.14
- Melting point of 263°C
- Extremely chemically stable
- No mildew or bacterial effects
- 4 - 4.5% of moisture regain
- Degraded by light as natural fibers
- Permanent set by heat and steam
- Abrasion resistant
- Easy to wash

Fine and highly flexible (nylon) fibers can control the dry shrinkage and micro-cracks, while the thick and highly stiff (steel) fibers are able to sustain the macro-cracks resulting from high stress. Further, these two types of fibers can complement each other and further improve the engineering properties of concrete. The nylon 6 fibre sample is as shown in Figure 2.

Figure 2: Nylon Fiber

F. Water

Portable water from tape is used for concrete casting and curing process as per IS456:2000 specifications. Good water is essential for quality concrete.

G. Super Plasticizer

Use of super plasticizers permits the reduction of water to the extent up to 30 per cent without reducing workability in contrast to the possible reduction up to 15 per cent in case of plasticizers. The use of super plasticizer is practiced for production of flowing, self-leveling, and self compacting and for the production of high strength and high performance concrete. Chemical admixture used is super plasticizer to increase the workability of concrete, manufacture by Conplast SP430 (Conplast Sp430 which is a Sulphonated Naphthalene Polymers based one).Very high workability in concrete.

H. Reinforcement

Steel is an alloy of iron and carbon. Apart from carbon by adding small percentage of manganese, sulphur, phosphorus, chrome nickel and copper special properties can be imparted to iron and variety of steels can be produced. Fe415 grade steel rods are used during the casting of beams. The diameter of main rod 12mm. Stirrups used in beams is 6mm in diameter. The reinforcement is as shown in Figure 3.

Figure 3: Reinforcements Details

I.Different Proportion of Fibres Used

TABLE 1. DIFFERENT PROPORTION OF FIBRES

M25 Grade	M30 Grade

Fibre	Fibre By % Volume	Fibre	Fibre By % Volume
CC	0	CC	0
Nylon	0.50	Nylon	0.50
Nylon	0.75	Nylon	0.75
Steel	0.75	Steel	0.75

J.Mix Design

Concrete for M25 grade and M30 grade Were prepared as per IS.10262:2009 with w/c 0.45 and 0.50.Mix proportion for M25 grade and M30 grade concrete for material was as follows

TABLE 2. QUANTITIES OF MATERIALS

M25 Grade	
Material	**Quantity**
Cement	394.32 kg/m^3
Fine Aggregate	660.13 kg/m^3
Coarse Aggregate	1151.35 kg/m^3
Water Content	197.16 kg/m^3
W/C	0.45

TABLE 3. QUANTITIES OF MATERIALS

M30 Grade	
Material	**Quantity**
Cement	438.13 kg/m^3
Fine Aggregate	629.47 kg/m^3
Coarse Aggregate	1145.72 kg/m^3
Water Content	197.16 kg/m^3
W/C	0.50

III. BEAMDETAILS AND TEST SETUP

A. Beam Details

In this study, total eight numbers of rectangular beam specimens were fabricated and tested. All the specimens were designed as under reinforcement according to IS 456. All beam specimens were singly reinforced beams. All specimens have the rectangular geometry with a cross sectional area of 150 mm x 200 mm and the length of the specimens was 2000 mm. Such beam size and length were chosen to conduct typical flexural failure. Concrete clear cover for all the beams was kept constant as 25 mm. The internal tension and hanger reinforcement of all beams were bent ninety degrees at both ends to fulfill the anchorage criteria. Two 12 and 10 mm diameter deformed hanger bars at the compression zone were used up to shear span zone. Steel bar of 10mm diameter was used as shear reinforcement and distributed only in the shear span to ensure that beams would fail under pure flexure.

B. BEAM TEST SETUP

Before testing, the beam was whitewashed and the location of neutral axis and center lines were marked. The beams were simply supported and tested under two-point loading as shown Figure4.

Figure 4: Beam Test Setup

IV. RESULTS AND DISCUSSION

A Slump Test

The workability test is carried out by slump cone apparatus. The slump cone apparatus used for test had height 300mm, diameter at top 200mm and diameter at bottom 100mm. Place the concrete in the mould in three layers, compact each layer 25 times with a tamping rod. Then remove the mould by raising it vertically. Then allow the concrete to subside. This subsidence is referred to slump of concrete. Measure the difference in level between the height of the mould and that of the highest point of subsided concrete. Take the difference in height in mm is taken as slump of concrete.

TABLE 4. SLUMP VALUE

Grade	Mix	Slump Value (mm)
M25	CC	88
	NF 0.50%	74
	NF 0.75%	78
	SF 0.75%	84
M30	CC	85
	NF 0.50%	72
	NF 0.75%	76
	SF 0.75%	80

B. Compression Strength Test

The compression test is carried out on specimens cubical in shape. The cube specimen is of the size 15 x 15 x 15 cm. If the largest nominal size of the aggregate does not exceed 20 mm. The mould was then filled with concrete in three layers and compacted using a tamping rod. Further, the moulds were placed on the vibrating table for 60 seconds to achieve proper compaction and subsequently maintained on a plane and level surface in the laboratory for 24 hours.

The cubes were demoulded and set aside for curing.

The compressive strength was calculated as follows:

Compressive strength (MPa) =

$$\frac{\text{Failure load}}{\text{cross sectional area}}$$

TABLE 5. COMPRESSION STRENGTH TEST

Grade	Mix	7 days Compressive Strength (N/mm^2)	28 days Compressive Strength (N/mm^2)
M25	CC	17.50	24.75
	NF 0.50%	18.35	25.55
	NF 0.75%	19.20	26.44
	SF 0.75%	20.71	27.91
M30	CC	21.06	29.77
	NF 0.50%	21.91	30.62
	NF 0.75%	22.75	31.46
	SF 0.75%	24.26	32.97

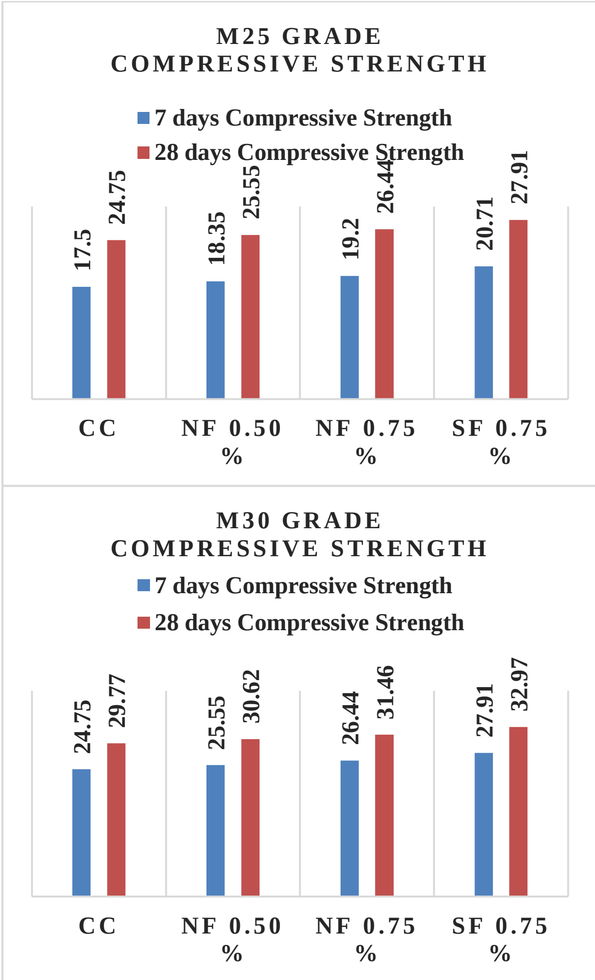
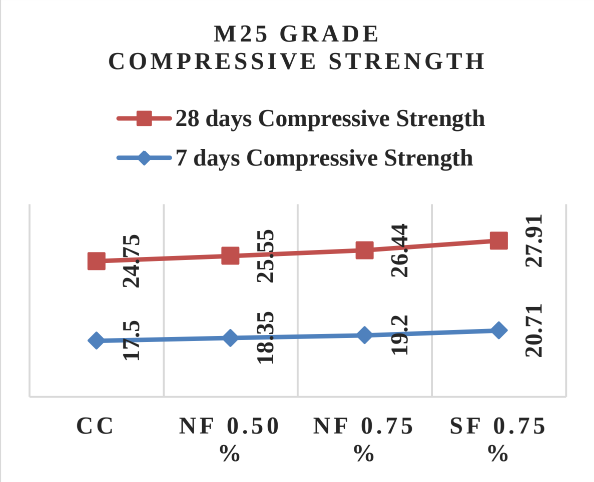


Figure 5:Compression Strength



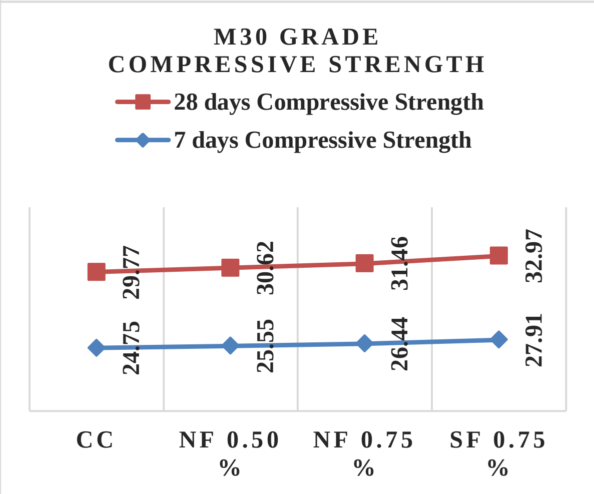


Figure 6:Compression Strength

C. SPLIT TENSILE TEST

Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the "pull" applied to the concrete and beam tests are found to be dependable to measure flexural strength property of concrete.

Cylinder specimen of size 150mm dia and 300mm height is used. The mould was then filled with concrete in three layers and compacted using a tamping rod. Further, the moulds were placed on the vibrating table for 60 seconds to achieve proper compaction and subsequently maintained on a plane and level surface in the laboratory for 24 hours. The cubes were demoulded and set aside for curing.

The Split tensile strength was calculated as follows:

Split tensile strength (MPa) = $\frac{2P}{\pi DL}$

TABLE 6. SPLIT TENSILE STRENGTH TEST

Grade	Mix	7 days Split Tensile Strength (N/mm^2)	28 days Split Tensile Strength (N/mm^2)
M25	CC	2.92	3.48
	NF 0.50%	2.99	3.53
	NF 0.75%	3.06	3.59
	SF 0.75%	3.18	3.69
M30	CC	3.21	3.81
	NF 0.50%	3.27	3.87
	NF 0.75%	3.33	3.92
	SF 0.75%	3.44	4.01

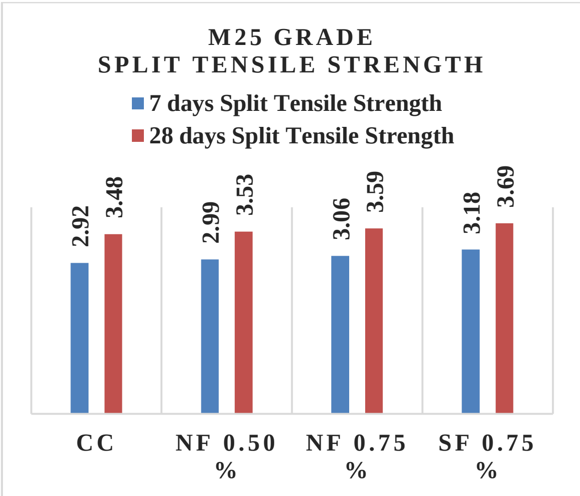


Figure 7:Split Tensile Strength

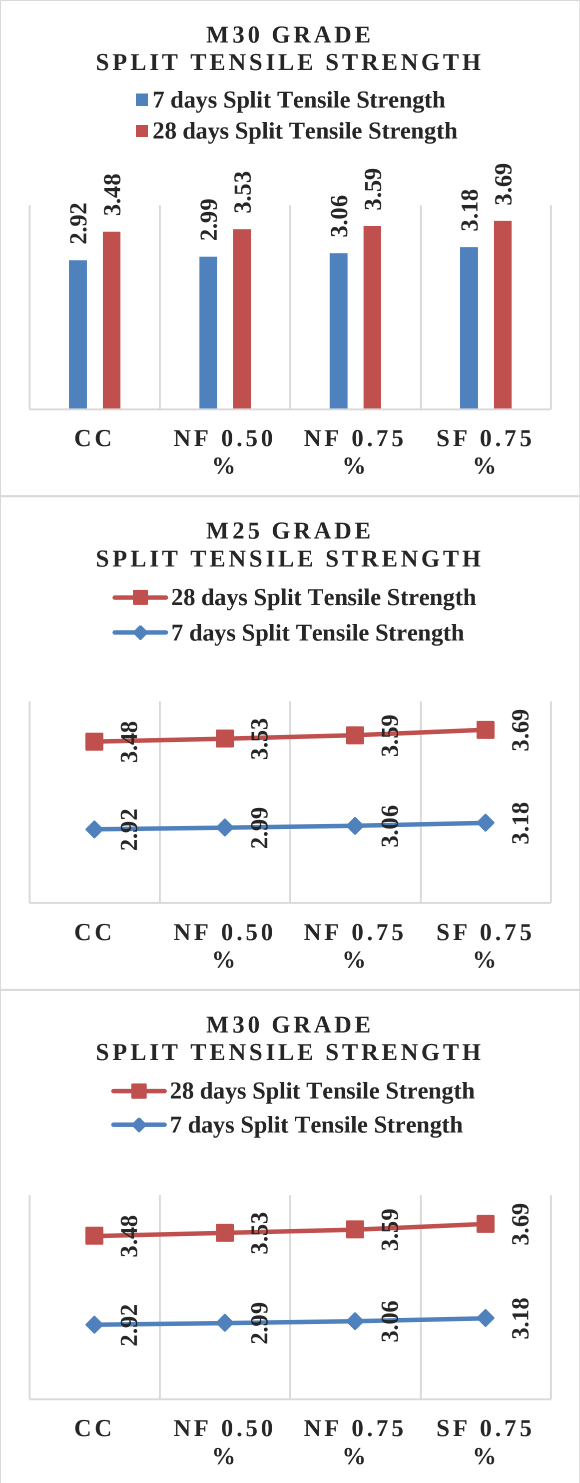


Figure 8:Split Tensile Strength

D. FLEXURAL STRENGTH TEST

Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces. Beam had 2000mm length, 150mm wide and depth 200mm. 2no's 12mm dia bars at bottom and 2no's 8mm dia bars at top and 130mm spacing 8mm dia stirrups is used as reinforcement.

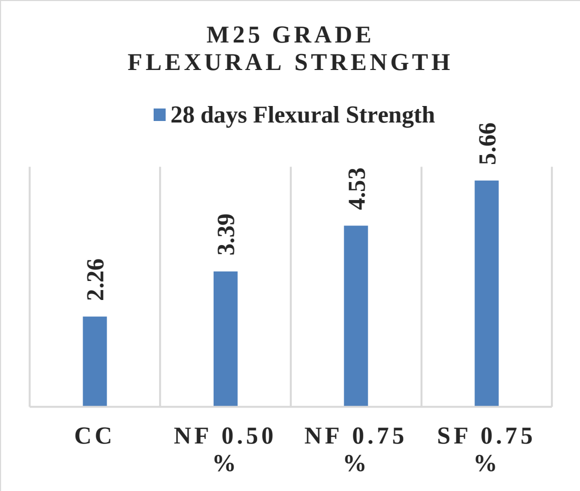
The cured specimens were tested under load frame instrument. The beam specimens were tested for midpoint loading and their deflection were observed with LVDT attached to the specimen. The readings were recorded in data logger attached to the loading frame instrument. Gradual loading has been imposed on the specimen through a load cell 100tons capacity until failure. Beam is tested and the ultimate load carrying capacity of beam is finding out by using test results. The variation between load and deformation is plotted as a graph.

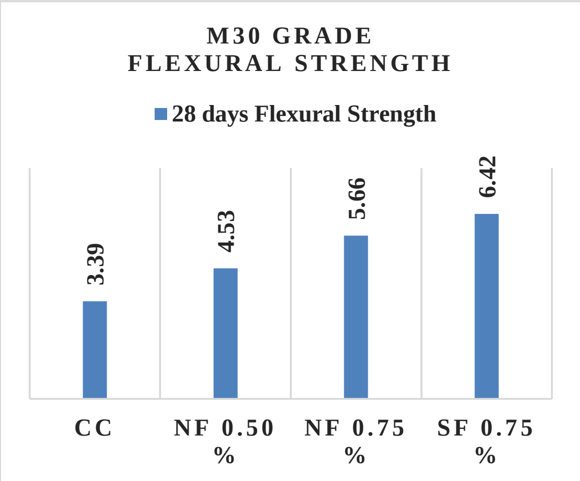
Figure 9: Beam Test and Crack Pattern

Figure 10: Beam Test and Crack Pattern

TABLE 7.FLEXURAL STRENGTH TEST

Grade	Mix	First Crack Load (KN)	First Crack Deflection (mm)
M25	CC	8	1.48
	NF 0.50%	12	1.61
	NF 0.75%	16	1.78
	SF 0.75%	20	2.73
M30	CC	12	1.39
	NF 0.50%	16	1.50
	NF 0.75%	20	1.64
	SF 0.75%	24	2.34
Grade	**Mix**	**Ultimate Load (KN)**	**Ultimate Deflection (mm)**
M25	CC	54	10.27
	NF 0.50%	58	12.03
	NF 0.75%	60	14.01
	SF 0.75%	64	16.47
M30	CC	58	8.50
	NF 0.50%	62	10.58
	NF 0.75%	64	12.52
	SF 0.75%	68	14.21
Grade	**Mix**	**Flexural Strength Initial ((N/mm^2)**	**Flexural Strength Ultimate (N/mm^2)**
M25	CC	2.26	15.29
	NF 0.50%	3.39	16.43
	NF 0.75%	4.53	16.99
	SF 0.75%	5.66	18.13
M30	CC	3.39	16.43
	NF 0.50%	4.53	17.56
	NF 0.75%	5.66	18.13
	SF 0.75%	6.42	19.26





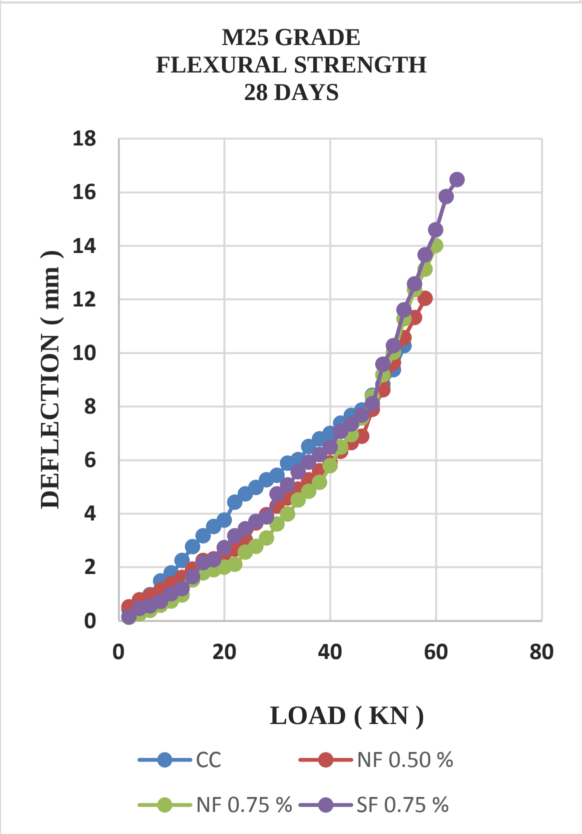


Figure 11: Flexural Strength

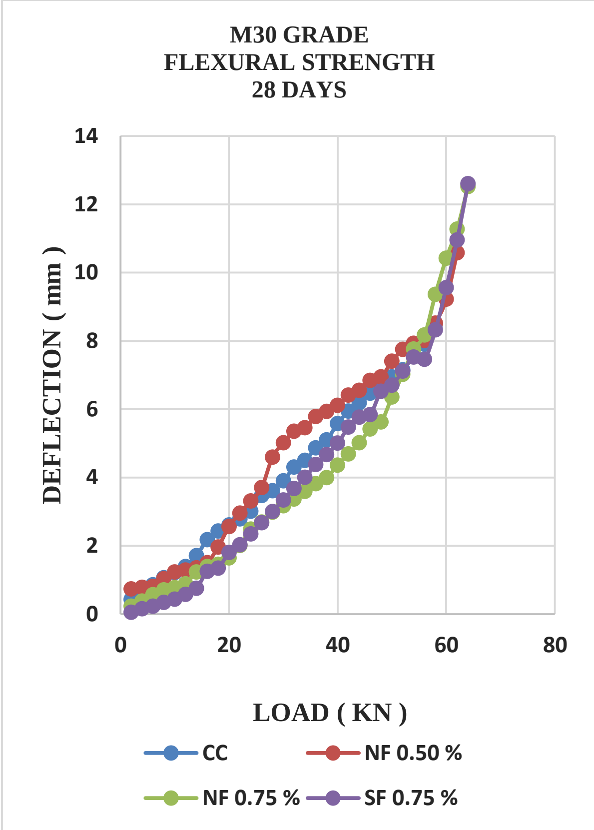


Figure 12: Flexural Strength

V. CONCLUSIONS

From my experimental investigation I concluded the following points.

- There is improvement in Compressive strength of Fibre Reinforced Concrete to Conventional Concrete because of addition of fibres. The maximum increase in compressive strength observed at having steel fibre ratio 0.75 % in M25 grade and M30 grade and when compared with controlled concrete the increase in compressive strength with fibre addition in percentage of 0.50 %, 0.75 % of nylon fibre and 0.75 % of steel fibre is 3.23 %, 6.83 % of nylon fibre and 12.77 % of steel fibre for M25 grade and 4.9 %,7.7 % of nylon fibre and 13.75 % of steel fibre respectively.
- Increase in Tensile strength when compared to Fibre Reinforced Concrete to Conventional Concrete.The maximum increase in tensile strength observed at having steel fibre ratio

0.75 % in M25 grade and M30 grade and when compared with controlled concrete the increase in tensile strength with addition of fibre in percentage of 0.50 %, 0.75 % of nylon fibre and 0.75 % of steel fibre is 3.68 %, 6.16 % of nylon fibre and 10.03 % of steel fibre for M25 grade and 4.77 %,7.9 % of nylon fibre and 11.25 % of steel fibre respectively.

- Flexural strength may be maximum for steel fibre 0.75 % when compares to conventional concrete. From this we can conclude that there is an increment in the fibre content there is also an increment in flexural strength. Thus flexural strength increases with the increase of addition of fibre in the mix. When compared with the controlled concrete the increase in flexural strength with fibre addition in percentage of 0.50 %, 0.75 % of nylon fibre and 0.75 % of steel fibre is 6.23 %, 8.99 % of nylon fibre and 13.03 % of steel fibre for M25 grade and 6.89 %, 9.46 % of nylon fibre and 13.92 % of steel fibre respectively.

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