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Behaviour of Steel Fibre Reinforced Concrete under Flexural Failure

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Abstract: *Steel fiber reinforced concrete (S.F.R.C) is distinguished from plain concrete by its ability to absorb large amount of energy and to withstand large deformations prior to failure. The preceding characteristics are referred to as toughness. Flexural toughness can be measured by taking the useful area under the load-deflection curve in flexure. Detailed experimental investigation was carried out to determine flexural toughness and toughness indices of SFRC the variables used in investigation were: reinforcement, steel fiber percentage by volume. The aim of this project is to present the findings of the investigation and equations obtained for predicting the desired flexural toughness and in turn the toughness indices for SFRC. These equations are dependent on the ultimate flexural strength, first crack multiple deflections and concrete specimen size. They are independent of the concrete matrix composition.*

The experimental program consists of casting and testing of 3 beams with steel fibers to compare our results with the steel fiber reinforced concrete. The beams used for tests were SFRC beam of size (700 mm x 150 mm x 150 mm) used hook end steel fibers in the concrete for determining flexural strength of concrete . The fiber reinforced concrete beam contains steel fibers in at the rate of 0%, 0.5%, 1%, 1.5% volume fraction of the beams. This experiment requires lots of trail work as I need to find out the maximum strength.

I. INTRODUCTION

Nowadays, the application of fiber reinforcement in concrete is not new. There are many researchers focused on fiber application. The fiber can be made from either natural material (asbestos, sisal and cellulose) or a manufactured product such as glass, steel, carbon and polymer (Guneyisi. E. et al., 2013). Among the various types of fibers, steel fiber is the most commonly used for most structural and non-structural purposes (Bolat,H et al,2014).In this research steel fiber have been used. The application of the steel fiber is mostly utilized in construction due to its ability in resisting the formation and growing of cracking, abrasion and enhances the flexural strength, fatigue strength of reinforced concrete (Altun. F. et al,, 2012). From the study, the tensile and flexural strength of concrete enhanced significantly due to addition of steel fiber (Shahiron.S.,2009). In this study, the behaviour of reinforced concrete beam with different aspect ratio of steel fiber added into mixture was focused. According to the ACI 544, 3R-08, aspect ratio is referred to the ratio of fiber length over the diameter. Normal range of aspect ratio for steel fiber is from 20-100mm. Aspect ratio of steel fiber greater than 100mm is not recommended because it will cause inadequate workability, formation of mat in the mix and also non uniform distributed.

The properties of the concrete in brittle material which is low in tensile strength and low in strain capacity. Low tensile strength and low strain at fracture were major deficiencies in plain concrete (Suguna. K. et al., 2015). The low tensile strength was attributed to numerous micro cracks in plain concrete. The rapid propagation at these cracks under applied stress was responsible for low tensile strength and brittle failure of material. In structural application, the concrete will provide the reinforcing bars to carry the tensile force once the concrete has cracked, so that it remains largely in compression under load. As mentioned earlier, tensile failure strain of the reinforced concrete is significantly lower than the yield strain of the steel reinforced and the concrete crack before any significant load to transfer to the steel. In industry application, the steel reinforced needed to carry the tension forces in the concrete.

According to the problem of steel reinforced concrete in structural application and needed in industry application, a new application of reinforced concrete needs to develop. So, from the previous research additional fiber is one of the methods to improve the mechanical properties of the structural concrete.

II. LITERATURE REVIEW

The application of fiber widely used in construction, by adding the fiber in concrete. Referring to the previous studies, the fibers can improve the mechanical and ductility of concrete, reduced the plastic shrinkage and improve the abrasion.

Batson etal., 1972 is reported that fatigue strength of 74% and 83% of the first crack static flexural strength at 2 million cycles of completely reversal and non-reversed loads respectively for a steel fiber content of 2.98% by volume .

Olivito.R.S., 2007, the failure mode is affected by the presence of fibers, while concrete elements usually fails suddenly and break in their middle section, steel fiber reinforced specimen started micro-cracking symmetrically on their side and fiber bridging effect abounded the sudden failure. From that, the steel fibers can improve the tensile strength of the concrete.

Rana.A,(2013) also mentioned in his studies that the steel fiber used in concrete to control cracking due to both of drying shrinkage and plastic shrinkage. Then the fibers also reduce the permeability of concrete and thus reduce bleeding of water. Among types of fibers such as glass, natural and synthetic polymer, the focus given on steel fiber because it is used in this research. The reason using the steel fiber because it can improve the durability of concrete and increase the impact resistance of concrete. Then, the steel fiber having a various types with different properties.

Pajak.M and Poniskiweski, 2013 were studied about the flexural behaviour of reinforced concrete beam with two different types shape of steel fiber. The result, based on the authors, both types of steel fiber in the reinforced concrete beam with higher fiber content indicated the higher flexural strength. The shape of steel fiber strongly influences the flexure strengthen concrete. From, the result, the hooked end steel fiber are more effectiveness to improving the flexural strength.

Suguna. K. et al., 2015, the properties of the concrete in brittle material which is low in tensile strength and low in strain capacity. Low tensile strength and low strain at fracture were major deficiencies in plain concrete.

III. MIX DESIGN OF M25

Grade Designation : M25
Type of Cement : OPC 53 Grade Conforming to IS 12269,2008
Maximum Nominal Size of Aggregate: 20mm
Minimum Cement Content : 300 kg/m^3
Maximum Water-Cement Ratio: 0.50
Workability (Slump) : 100mm
Exposure Condition : Moderate
Method of Concrete Placing : Hand
Degree of Supervision : Good
Type of Aggregate : Crushed Angular Aggregate
Maximum Cement Content : 450 kg/m^3
Chemical Admixture Type : Super plasticizer (PermaRheoplast)

(a) Test Data for Materials:

Cement Used : OPC 53 Grade Conforming to IS 8112
Specific Gravity of Cement : 3.15
Chemical Admixture : Super plasticizer Conforming IS 9103

(b) Specific Gravity of:

Cement : 3.15
Coarse Aggregate (20 mm down): 2.60
Coarse Aggregate (10mm down): 2.60
Fine Aggregate : 2.59
Admixture : 1.26

©.Water absorption:

Coarse Aggregate (20 down) : 0.019 %
Coarse Aggregate (10 down) : 2.54 %
Fine Aggregate : 0.29 %

(d) Free (Surface) Moisture:

Coarse aggregate : Nil

Fine aggregate : Nil

(e) Sieve Analysis:

Coarse aggregate : Graded

Fine aggregate : Zone-I

(f) Target Mean Strength

$f_t = f_{ck} + 1.65\ s$

$= 25 + 1.65 \times 4.0$

$= 31.60\ N/mm^2$

(g) Selection of Water-Cement Ratio:

From Table 5 of IS 456,

the maximum water cement Ratio for M25 grade is 0.50. Based on experience, adopt water-cement ratio as 0.48

(h) Selection of Water Content:

Maximum water content = 186 liter (for 25 to 50 mm Slump range) for 20mm aggregate

Estimate water content for 75mm slump = 186 + (6/100) x186

= 197 liters

As Super plasticizer is used, the water content can be reduced up to 9 percent and above, Hence, the arrived water content = 197 x 0.91

= 180 liters

(i) Calculation of Cement Content

Water-cement ratio = 0.48

Cement content = 180/ 0.48

= 375 kg/m^3

From Table 5 of IS 456, minimum cement content for moderate condition is 300 kg/m^3.

Super plasticizer admixture @ 1% of the total cement content = 375 x (1/100)

= 3.75 kg/m^3

So, Total cement content = 375 – 3.75

= 371.25 kg/m^3

(j) Proportion of Volume of Coarse Aggregate and Fine Aggregate Content

From Table 3 of IS10262:2009, volume of the coarse aggregate to 20 mm size aggregate and fine aggregate for water cement ratio of 0.50 is 0.60

In the present case the water cement ratio is 0.48

Therefore the corrected proportion of volume of coarse aggregate for water cement ratio of 0.48 is 0.604

Therefore,

Volume of coarse aggregate = 0.604

Volume of fine aggregate = 1.00-0.604

= 0.396

(k) Mix Calculations:

The mix calculation per unit volume of concrete shall be as follows:

a) Volume of concrete = 1m^3

b) Volume of cement = (mass of cement /sp. Gravity of cement) x (1/1000)

= 0.118 m^3

c) Volume of water = (mass of water/ sp. Gravity of water) x (1/1000)

= 180/1000

= 0.180 m^3

d) Volume of chemical = (mass of admixture/sp. Gravity of admixture) x (1/1000)

Admixture (super plasticizer @ =(3.75/1.26) x (1/1000)

1% by mass of cementations = 0.003 m^3 Material)

e) Volume of all aggregates = {a – (b + c + d)}

= 0.699 m^3

f) Mass of coarse aggregate (20 down) = e x Volume x Specific gravity x 1000

= 0.699 x 0.39 x 2.6 x 1000

= 709 kg

g) Mass of coarse aggregate (10 down) = 0.699 x 0.214 x 2.6 x 1000

= 389 kg

h) Mass of fine aggregate (sand) = 0.699 x 0.396 x 2.59 x 1000

= 717 kg

(l) Mix proportions for trial number *1:*

Cement = 371.25 kg/m^3

Water = 180 kg/m^3

Fine aggregates = 717 kg/m^3

Coarse aggregates

(20 DN, 10 DN) = (709, 389) kg/m3

Chemical admixture = 3.75 kg/m^3

Water - cement ratio = 0.48

(m) Material Required For 3 Beams*:*

Size of Beam to be casted =700mm x 150mm x 150mm

= 15750000 mm^3

Number of Beam to be casted = 3

Volume of 3 Beam = 3 x 15750000

= 47250000 mm^3

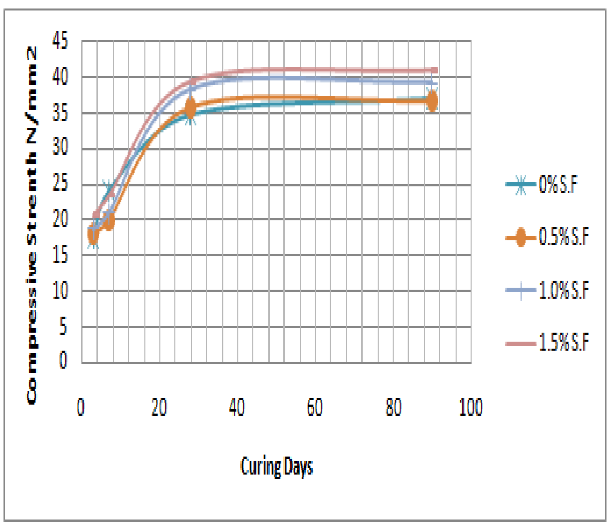
Increase 25% for Wastage = 1.25 x 47250000

= 59062500 mm^3

IV. TEST RESULTS

Table 1- Test Result for Compressive Strength (aspect ratio@65) @ Different curing period of SF

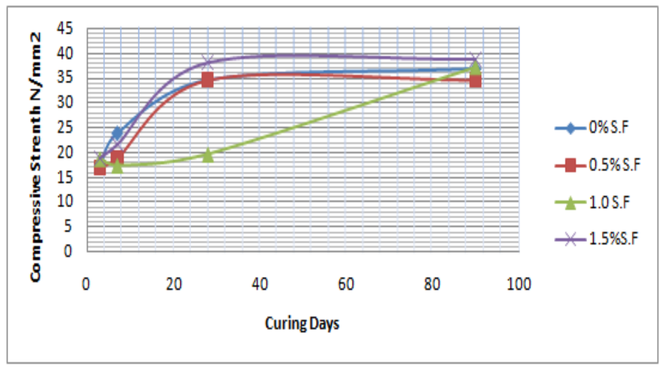
S. NO:	Curing Days	Compressive Strength (N/mm^2)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	17.30	17.91	18.74	20.53
2	7	23.85	19.77	21.00	23.28
3	28	34.56	35.68	38.26	39.36
4	90	36.80	36.56	39.24	40.92



Graph .1-Test Result for Compressive Strength at different Percentages of SF

Table 2 - Test Result for Compressive Strength (aspect ratio@80) @ Different curing period of SF.

S.NO:	Curing Days	Compressive Strength (N/mm^2)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	17.30	16.88	18.74	18.90
2	7	23.85	18.73	17.37	21.65
3	28	34.56	34.57	19.63	38.25
4	90	36.80	34.58	37.15	38.94



Graph 2-Test Result for Compressive Strength at different Percentages of SF

Table 3- Test Result for Flexural strength (aspect ratio@65) @ Different curing period of SF

S.NO:	Curing Days	Flexural strength (N/mm^2)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	7.47	8.8	9.47	10.40
2	7	7.80	9.76	10.38	11.20
3	28	8.00	10.00	10.73	11.40
4	90	8.40	10.40	11.00	11.6

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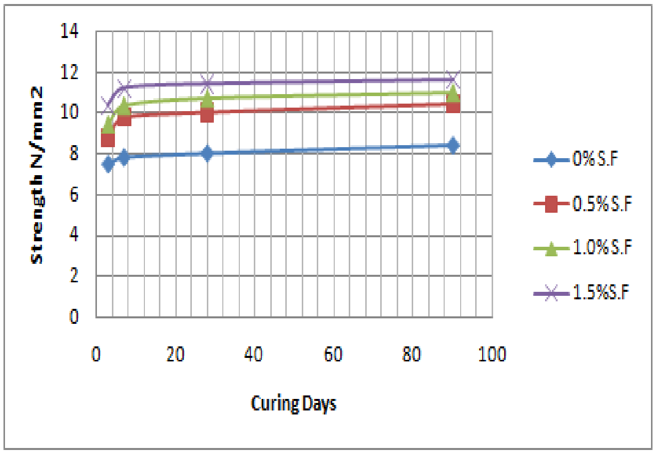
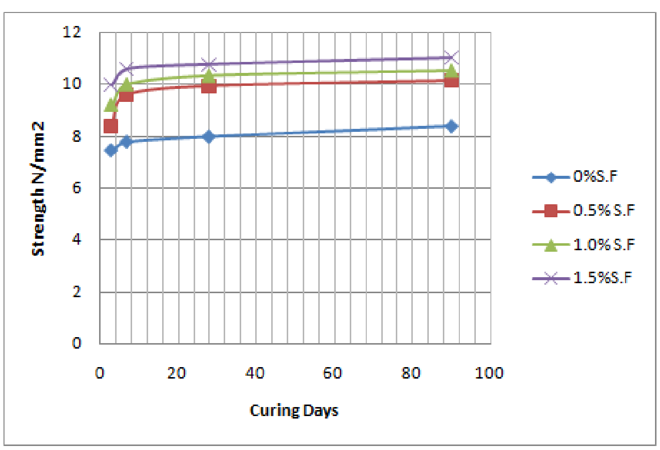


Graph.3- Test Result for Flexural strength (aspect ratio@65) @ Different curing period of SF

Table 4. Test Result for Flexural strength (aspect ratio@80) @ Different curing period of SF

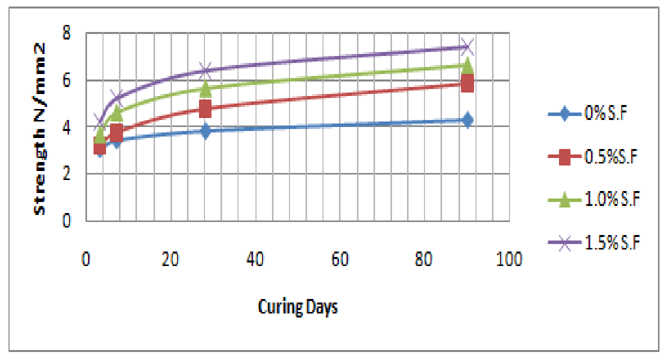
S.NO:	Curing Days	Flexural strength (N/mm^2)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	7.47	8.40	9.20	10.00
2	7	7.80	9.60	10.00	10.63
3	28	8.00	9.93	10.33	10.80
4	90	8.40	10.13	10.53	11.06



Graph 4. Test Result for Flexural strength (aspect ratio@80) @ Different curing period of SF

Table 5 Test Result for Spilt Tensile strength (aspect ratio@65) @ Different curing period of SF

SI. NO :	Curing Days	Spilt Tensile strength (N/mm^2)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	3.07	3.21	3.68	4.25
2	7	3.46	3.78	4.63	5.23
3	28	3.86	4.77	5.67	6.40
4	90	4.34	5.84	6.67	7.40



Graph 5: Test Result for Spilt Tensile strength (aspect ratio@65) @ Different curing period of SF

Table 6 Test Result for Spilt Tensile strength (aspect ratio@80) @ Different curing period of SF

SI.NO:	Curing Days	Spilt Tensile strength (N/mm^2)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	3.07	3.16	3.63	4.20
2	7	3.46	3.39	4.23	4.80
3	28	3.86	4.22	5.23	6.03
4	90	4.34	5.22	6.23	7.00

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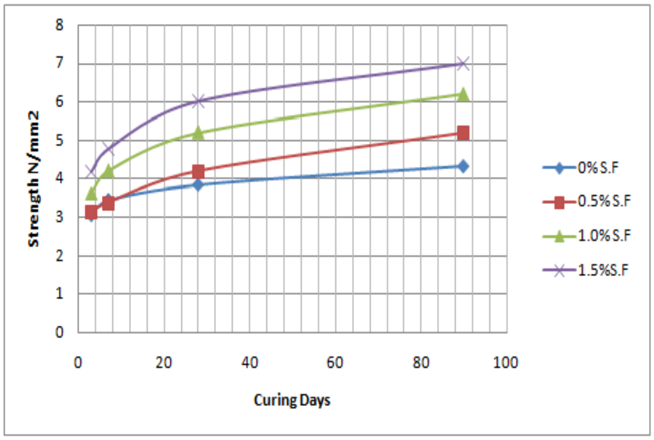


Graph 6: Test Result for Spilt Tensile strength (aspect ratio@80) @ Different curing period of SF

B) MIX DESIGN OF M50

Grade Designation : M50
Type of Cement : OPC 53 Grade
Conforming to IS 12269, 2008
Maximum Nominal Size of Aggregate: 20mm
Minimum Cement Content : 400 kg/m^3
Maximum Water-Cement Ratio: 0.40
Workability : 100mm
(Slump)
Exposure Condition : Moderate
Method of Concrete Placing : Hand
Degree of Supervision : Good
Type of Aggregate : Crushed
Angular Aggregate
Chemical Admixture Type : Super
plasticizer (PermaRheoplast)

(c) Test Data for Materials:

Cement Used : OPC 53 Grade
Conforming to IS 8112
Specific Gravity of Cement : 3.15
Chemical Admixture : Super
plasticizer Conforming IS 9103

(d) Specific Gravity of:

Cement : 3.15
Coarse Aggregate (20 mm down) : 2.60
Coarse Aggregate (10mm down) : 2.60
Fine Aggregate : 2.59
Admixture : 1.26

©.Water absorption:

Coarse Aggregate (20 down) : 0.019 %
Coarse Aggregate (10 down) : 2.54 %
Fine Aggregate : 0.29 %

(n) Free (Surface) Moisture:

Coarse aggregate : Nil
Fine aggregate : Nil

(o) Sieve Analysis:

Coarse aggregate : Graded
Fine aggregate : Zone-I

(p) Target Mean Strength

$f_t = f_{ck} + 1.65\ s$
$= 50 + 1.65 \times 5.0$
$= 58.250$ N/mm^2

(q) Selection of Water-Cement Ratio:

From Table 5 of IS 456,
the maximum water cement Ratio for M50 grade is 0.40. Based on experience, adopt water-cement ratio as 0.35

(r) Selection of Water Content:

Maximum water content = 186 liter (for 25 to 50 mm Slump range) for 20mm aggregate

Estimate water content for 100mm slump = 186 + (6/100) x186
= 197 liters

As Super plasticizer is used, the water content can be reduced up to 9 percent and above, Hence, the arrived water content = 197 x 0.91
= 180 liters

(s) Calculation of Cement Content

Water-cement ratio = 0.35
Cement content = 180/ 0.35 = 514 kg/m^3

From Table 5 of IS 456, minimum cement content for moderate condition is 400 kg/m^3.

Super plasticizer admixture @ 1% of the total cement content
= 514 x (1/100) = 5.14 kg/m^3

So, Total cement content 514 – 5.14 = 508.86 kg/m^3

(t) Proportion of Volume of Coarse Aggregate and Fine Aggregate Content

From Table 3 of IS10262:2009, volume of the coarse aggregate to 20 mm size aggregate and fine aggregate for water cement ratio of 0.50 is 0.60

In the present case the water cement ratio is 0.35
Therefore the corrected proportion of volume of coarse aggregate for water cement ratio of 0.35 is 0.63
Therefore,
Volume of coarse aggregate = 0.63
Volume of fine aggregate = 1.00-0.63
= 0.370

(u) Mix Calculations:

The mix calculation per unit volume of concrete shall beas follows:
a) Volume of concrete = 1m^3
b) Volume of cement = (mass of cement /sp. Gravity of cement) x(1/1000)
= 0.162 m^3
c) Volume of water = (mass of water/ sp. Gravity of water)x(1/1000)
= 180/1000 = 0.180 m^3
d) Volume of chemical = (mass of admixture/sp. Gravity ofadmixture) x (1/1000)
Admixture (super plasticizer @ = (5.14/1.26) x (1/1000)
1% by mass of cementations = 0.004 m^3 Material)
e) Volume of all aggregates = {a – (b + c + d)}
= 0.654 m^3
f) Mass of coarse aggregate (20 down) = e x Volume x Specific gravity x 1000
= 0.654 x 0.345 x 2.6 x 1000
= 587 kg
g) Mass of coarse aggregate (10 down) = 0.654 x 0.285 x 2.6 x 1000
= 485 kg
h) Mass of fine aggregate (sand) = 0.654 x 0.370 x 2.59 x 1000
= 627 kg

(v) Mix proportions for trial number *1:*

Cement = 508.86 kg/m^3
Water = 180 kg/m^3
Fine aggregates = 627 kg/m^3
Coarse aggregates
(20 DN, 10 DN) = (587, 485) kg/m3
Chemical admixture = 5.140kg/m^3
Water - cement ratio = 0.35

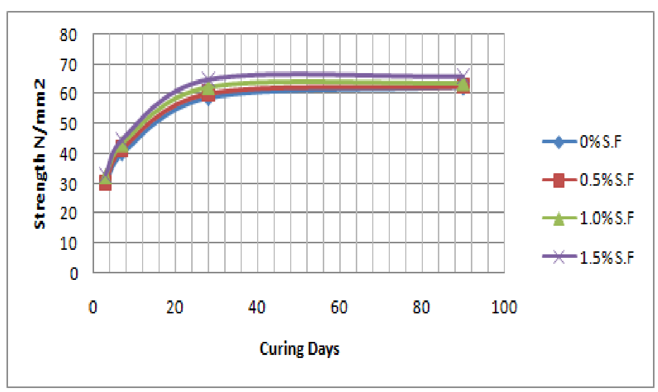
(w) Material Required For 3 Beams:

Size of Beam to be casted = 700mm x 150mm x 150mm =15750000 mm^3
Number of Beam to be casted = 3
Volume of 3 Beam = 3 x 15750000
= 47250000 mm^3
Increase 25% for Wastage = 1.25 x 47250000 = 59062500 mm^3

Following Tables/graphs give compressive strength, flexural strength and Split Tensile strength result for **M-50** grade of concrete with 0%, 0.5%, 1% and 1.5% steel fibers for aspect ratio, 65 and 80.

Table 7- Test Result for Compressive Strength (aspect ratio@65) @ Different curing period of SF - M50

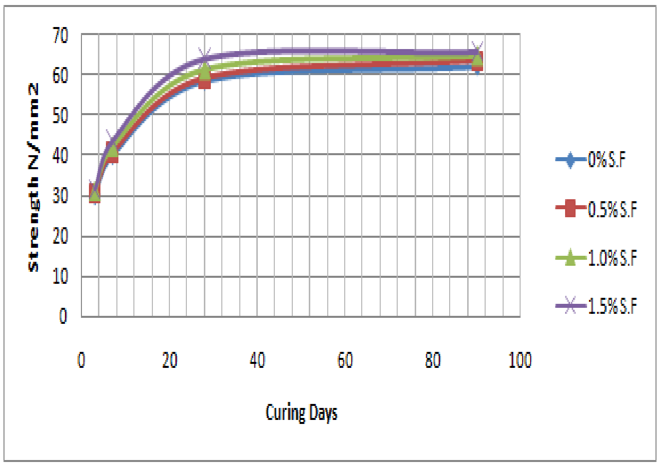
SI.NO:	Curing Days	COMPRESSIVE Strength (N/mm^2)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	30.19	30.64	32.5	33
2	7	40.15	41.89	43.45	44.87
3	28	58.67	60.32	62.5	65.06
4	90	62.25	62.67	63.89	66.1



Graph 7- Test Result for Compressive Strength (aspect ratio@65) @ Different curing period of SF

Table 8- Test Result for Compressive Strength (aspect ratio@80) @ Different curing period of SF -M50

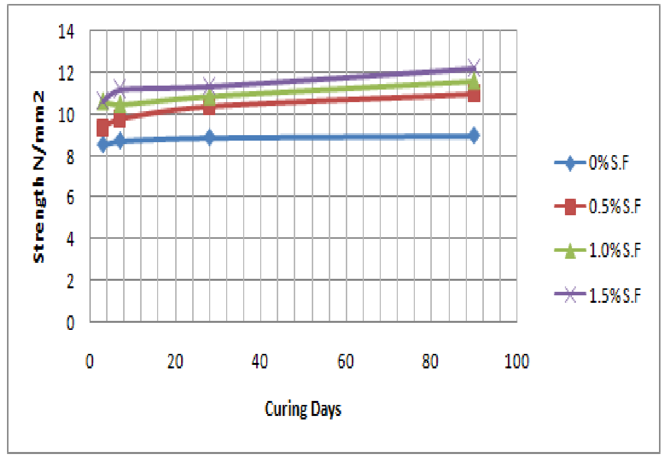
SI.NO:	Curing Days	COMPRESSIVE Strength (N/mm²)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	30.19	30.56	31.32	31.82
2	7	40.15	40.71	42.27	43.69
3	28	58.67	59.14	61.32	63.88
4	90	62.25	63.49	64.71	65.59



Graph 8- Test Result for Compressive Strength (aspect ratio@80) @ Different curing period of SF

Table 9- Test Result for Flexural strength (aspect ratio@65) @ Different curing period of SF - M50

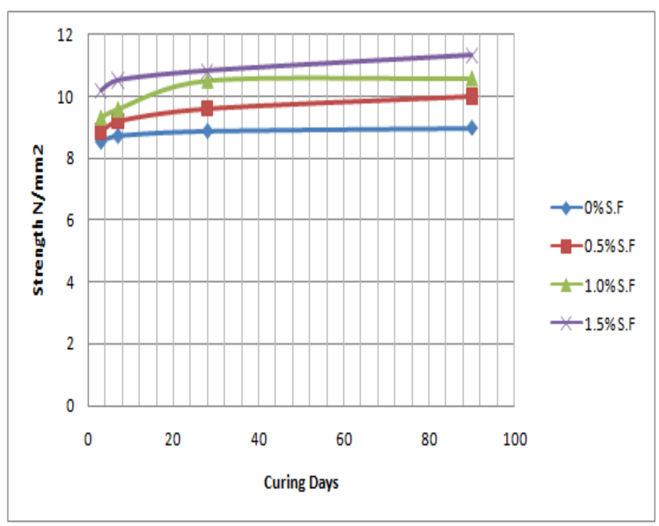
SI. NO:	Curing Days	Flexural strength (N/mm²)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	8.53	9.4	10.6	10.65
2	7	8.72	9.8	10.46	11.20
3	28	8.88	10.4	10.86	11.35
4	90	8.98	11	11.6	12.2



Graph 9 - Test Result for Flexural strength (aspect ratio@65) @ Different curing period of SF

Table 10- Test Result for Flexural strength (aspect ratio@80) @ Different curing period of SF - M50

SI. NO	Curing Days	Flexural strength (N/mm²)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	8.53	8.86	9.33	10.20
2	7	8.72	9.2	9.6	10.53
3	28	8.88	9.6	10.53	10.83
4	90	8.98	10	10.6	11.33



Graph 10- Test Result for Flexural strength (aspect ratio@80) @ Different curing period of SF

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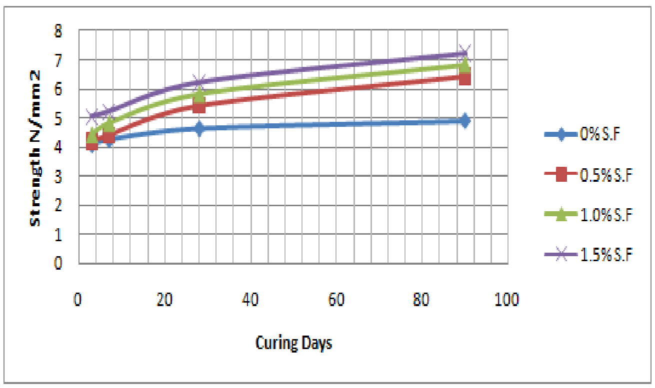
Table 11- Test Result for Spilt Tensile strength (aspect ratio@65) @ Different curing period of SF - M50

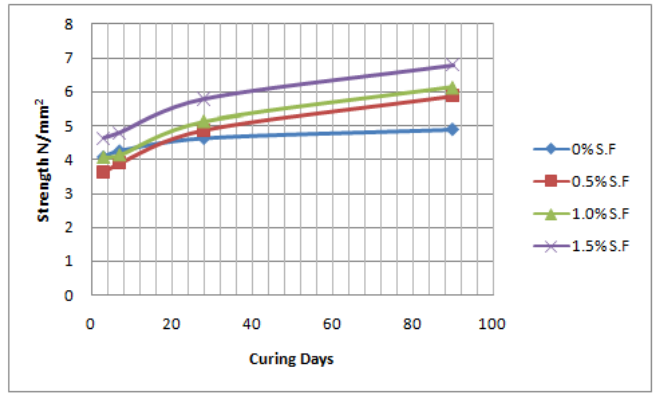
SI. NO	Curing Days	Spilt Tensile strength (N/mm2)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	4.07	4.21	4.43	5.06
2	7	4.25	4.42	4.82	5.23
3	28	4.63	5.42	5.82	6.23
4	90	4.89	6.42	6.82	7.23



Graph 11- Test Result for Spilt Tensile strength (aspect ratio@65) @ Different curing period of SF

Table 12- Test Result for Spilt Tensile strength (aspect ratio@80) @ Different curing period of SF -M50.

SL. NO	Curing Days	Spilt Tensile strength (N/mm^2)			
		0 % of SF	0.5 % of SF	1.0 % of SF	1.5 % of SF
1	3	4.07	3.62	4.06	4.63
2	7	4.25	3.90	4.13	4.79
3	28	4.63	4.87	5.13	5.79
4	90	4.89	5.87	6.13	6.79



Graph 12-Test Result for Spilt Tensile strength (aspect ratio@80) @ Different curing period of SF

V. CONCLUSION

M 25 GRADE

The following conclusions could be drawn from the present investigation.

1. It is observed that compressive strength, split tensile strength and flexural strength are on higher side for 1.5% fibers as compared to that produced from 0%, 0.5% 1% and 1.5 fibers.

2. All the strength properties are observed to be on higher side for aspect ratio of 65 as compared to those for aspect ratio 80.

3. It is observed that compressive strength of M25 grade concrete increases from 0.24% to 11.9% with addition of steel fibers for aspect ratio 65 and compressive strength increases from 0.95% to 5.81% with addition of steel fibers for aspect ratio 80.

4. It is observed that flexural strength of M25 grade concrete increases from 23% to 38.09% with addition of steel fibers for aspect ratio 65 and flexural strength increases from 20.59% to 31.66% with addition of steel fibers for aspect ratio 80.

5. It is observed that split tensile strength of M25 grade concrete increases from 34.56% to 70.5% with addition of steel fibers for aspect ratio 65 and split tensile strength increases from 20.27% to 61.29% with addition of steel fibers for aspect ratio 80.

6. It is observed that compressive strength of M50 grade concrete increases from 0.67% to 6.18% with addition of steel fibers for aspect ratio 65 and compressive strength increases from 1.99% to 5.36% with addition of steel fibers for aspect ratio 80.

7. It is observed that flexural strength of M50 grade concrete increases from 22.49% to 35.85% with addition of steel fibers for aspect ratio 65 and flexural strength increases from 11.35% to 26.16% with addition of steel fibers for aspect ratio 80.

8. It is observed that split tensile strength of M50 grade concrete increases from 31.28% to 47.85% with addition of steel fibers for aspect ratio 65 and split tensile strength increases from 20.04% to 38.85% with addition of steel fibers for aspect ratio 80.

M50 GRADE

The following conclusions could be drawn from the present investigation.

1. It is observed that compressive strength, split tensile strength and flexural strength are on higher side for 1.5% fibers as compared to that produced from 0%, 0.5% 1% and 1.5 fibers.
2. All the strength properties are observed to be on higher side for aspect ratio of 65 as compared to those for aspect ratio 80.
3. It is observed that compressive strength of M25 grade concrete increases from 0.24% to 11.9% with addition of steel fibers for aspect ratio 65 and compressive strength increases from 0.95% to 5.81% with addition of steel fibers for aspect ratio 80.
4. It is observed that flexural strength of M25 grade concrete increases from 23% to 38.09% with addition of steel fibers for aspect ratio 65 and flexural strength increases from 20.59% to 31.66% with addition of steel fibers for aspect ratio 80.
5. It is observed that split tensile strength of M25 grade concrete increases from 34.56% to 70.5% with addition of steel fibers for aspect ratio 65 and split tensile strength increases from 20.27% to 61.29% with addition of steel fibers for aspect ratio 80.
6. It is observed that compressive strength of M50 grade concrete increases from 0.67% to 6.18% with addition of steel fibers for aspect ratio 65 and compressive strength increases from 1.99% to 5.36% with addition of steel fibers for aspect ratio 80.
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8. It is observed that split tensile strength of M50 grade concrete increases from 31.28% to 47.85% with addition of steel fibers for aspect ratio 65 and split tensile strength increases from 20.04% to 38.85% with addition of steel fibers for aspect ratio 80.

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