Study of Fiber Reinforced Concrete Subjected to Elevated Temperature

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Abstract - *Fiber reinforced concrete is increasingly being used for various civil infrastructure applications worldwide. With the introduction of fiber materials in concrete, the knowledge about the effect of fiber percentage on the residual strength of concrete after subjecting to elevated temperature is less. Fire represents one of the most severe exposure conditions in structures. Hence provisions for appropriate fire resistance for structural members are major safety requirements for any building design. This project aims at studying the performance of steel fiber and polyester fiber reinforced concrete with varying percentage subjected to elevated temperatures. Totally 48 beams of size (0.5*0.1*0.1m) have casted with 0% fiber, 1% steel fiber. Flexural strength test have been conducted on these casted beams using universal testing machine and results compared with residual strength with different temperature of varied percentage of fibers.*

***Key Words*: Fibre reinforced, Polyesters, Steel fibres, Flexural strength, Deflection, Elevated temperature etc**

1. INTRODUCTION

Since ancient times, fibers have been used to reinforce brittle materials. Straw was used to reinforce sun-baked bricks and horse hair was used to reinforce masonry mortar and plaster. In modern times, a wide range of engineering materials (including ceramics, plastics, and cement and gypsum products) incorporate fibers to enhance composite properties. The enhanced properties include tensile strength, compressive strength, elastic modules, crack resistance, crack control, durability, fatigue life, resistance to impact and abrasion, shrinkage, expansion, thermal characteristics and fire resistance. Concrete also have remarkable fire resisting properties. In most of the cases of accidental fire, it is found that concrete failure depends on the intensity and duration of fire. Exposure of concrete to fire may result in cracking, spalling during heating and disintegration during cooling. To reduce cracking, spalling and disintegration of concrete many attempts have been made. One of the attempts is the introduction of fibers in concrete.

1.1 Fiber Reinforced Concrete

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. This stone like material is a brittle material which is strong in compression but very weak in tension. The cracks gradually propagate to the compression end of the member and finally, the member breaks. This shortcomings are traditionally overcome by adding reinforcing bars or pre stressing steel. Fibers are discontinuous are generally distributed randomly throughout the concrete matrix. Fibers are being used in structural applications with conventional reinforcement, because of the flexibility in methods of fabrication. Fiber reinforced concrete can be an economic and useful construction materials.

1.2 Polyester Fibers

Polyester is a category of polymers which contain the ester functional group in their main chain. Although there are many polyesters, the term polyester, as a specific material most commonly refers to polyethylene terephthalate (pET). Natural polyesters and a few synthetic ones are biodegradable, but most synthetic polyesters are not' Depending on the chemical structure, polyester can be a thermoplastic or thermo set; however, the most common polyesters are thermoplastics till Liquid crystalline polyesters are among the first industrially used liquid crystal polymers.

1.3 Steel Fibers

Concrete is the most widely used structural material in the world with an annual production of over seven billion tons. For a variety of reasons, much of this concrete is cracked. It is now well established that steel fiber reinforcement offers a solution to the problem of cracking by making concrete tougher and more ductile. It has also been proved by extensive research and field trials carried out over the past three decades, that addition of steel fibers to conventional plain or reinforced and pre stressed concrete members at the time of mixing/production imparts improvements to several properties of concrete, particularly those related to strength, performance and durability. The efficiency of steel fibers as concrete macro-reinforcement is in proportion to increasing fiber content, fiber strength, aspect ratio and bonding efficiency of the fibers in the concrete matrix.

2. SCOPE AND OBJECTIVE

i. Scope

The main scope of the present investigation is to study the effect of elevated temperatures on the steel fiber, polyester fiber. Different mixes were prepared by varying the quantity of steel fibers, polyester in terms of 0%, 1% of the total volume of concrete. Beams made of above two mixes were subjected to elevated temperatures i.e., 100^{0}C, 200^{0}C, 300^{0}C, 400^{0}C, 500^{0}C, 600^{0}C and 800^{0}C.

ii. Objective

The present investigation is carried out with the following objective;

- To study the flexure strength of beams after subjecting to different elevated temperatures for 2 hours duration.
- To measure the deformation of beams at particular load intervals using dial-gauge.

3. MATERIALS AND ITS PROPERTIES

The Various types of materials used in FRC are

i. Cement used is Portland pozzolana cement (PPC)
Specific gravity of cement = **3.16**
Normal Consistency of Cement, **P = 31%**

ii. Fine aggregate
Specific gravity of Fine Aggregate, **G= 2.53**
Water absorption of fine aggregate = **1.9%**
The Fine Aggregates tested confirms to **Zone-II** as per IS-383-1990

iii. Coarse aggregate
Specific gravity of Fine Aggregate, **G= 2.62**
Water absorption of fine aggregate = **0.4%**
Aggregate impact value = **30%**
Aggregate crushing value = **32%**
Coarse aggregate tested confirms to the size of 10 mm of nominal size of aggregates as per IS 383 – 1970

4. MIX PROPORTION

For 1m^3 volume of concrete,
Cement = 400 kg
Water = 140 kg
Fine aggregate = 892.6 kg
Coarse aggregate = 924.5 kg
W/C ratio = 0.35

5. MIXING, CASTING AND CURING

All the ingredients required for the preparation of concrete were effectively mixed manually (hand mixing) on a large steel tray. First, all the dry ingredients such as cement, fine aggregates, coarse aggregates and polyester fibers and steel fibers were mixed for 3 minutes, after which water was added based on the quantity determined from the mix design and then all the ingredients were mixed thoroughly for about 4 minutes.

The mixed concrete was poured in to the beams moulds of size 0.5m×0.1m×0.1m. All the specimens were prepared in accordance with IS 516:1959. The beams were compacted using table vibrator or needle vibrator in 3 layers for 30sec each. Numbers of beams casted were 96.

Curing of the specimens was carried out by immersing the specimens in a curing tank of dimensions 3m × 1m ×1m.The beams were placed in the tank for a period of 28 days and then removed for further testing.

Fig 5.1 Mixing of materials

Fig 5.2 Casting

Fig 5.3 Curing

Table 5.1 Details of Number of beams

SL.NO	DISCRIEPTION	TEMPERATURE	NUMBER OF BEAMS
1	0% FIBER	room temperature	3
		100	3
		200	3
		300	3
		400	3
		500	3
		600	3
		800	3
2	1% STEEL FIBER	room temperature	3
		100	3
		200	3
		300	3
		400	3
		500	3
		600	3
		800	3
	Total number of beams		48

6. TEST RESULTS

Table 6.1 Variation of Weight Loss of specimens

Tem	Spec Type	Spec No	W1 Before Fire	W2 After Fire	Weight Loss
100	0% fiber	1	12.1	11.9	0.2
		2	12.3	12	0.3
		3	12.1	11.8	0.3
	1% steel fiber	1	12.4	11.9	0.5
		2	12.4	11.8	0.6
		3	12.4	11.9	0.5
200	0% fiber	1	12	11.5	0.5
		2	12	11.5	0.5
		3	12	11.9	0.1
	1% steel fiber	1	12.4	11.9	0.5
		2	12.3	11.9	0.4
		3	12.4	12	0.4
300	0% fiber	1	12.6	11.6	1
		2	12.3	11.6	0.7
		3	12.1	11.6	0.5
	1% steel fiber	1	12.6	11.5	1.1
		2	12.2	12.5	-0.3
		3	12.2	12.4	-0.2
400	0% fiber	1	11.3	10.9	0.4
		2	11.5	11.2	0.3
		3	11.5	11.2	0.3
	1% steel fiber	1	12.5	11.8	0.7
		2	12.4	11.5	0.9
		3	12.5	11.8	0.7
500	0% fiber	1	11.9	10.6	1.3
		2	12.2	11.1	1.1
		3	12.2	10.6	1.6
	1% steel fiber	1	12.5	11.9	0.6
		2	12.4	11.6	0.8
		3	12.5	11.9	0.6
600	0% fiber	1	12.2	11.3	0.9
		2	12.3	11.6	0.7
		3	12.3	11.6	0.7
	1% steel fiber	1	11.9	11.2	0.7
		2	12.3	11.2	1.1
		3	12.3	11.5	0.8
800	0% fiber	1	12.2	11	1.2
		2	11.8	11.4	0.4
		3	12.2	11.4	0.8
	1% steel fiber	1	12.2	11.3	0.9
		2	11.8	10.6	1.2
		3	12.2	11.3	0.9

Fig 6.1 Beams Placed in Electric Oven

Table 6.2 Variation of Flexural Strength with 0% Fiber

Temperature (°C)	Flexural strength (MPa)
27	4.75
100	4.65
200	3.78
300	3.5
400	2.22
500	1.83
600	1.65
800	0.45

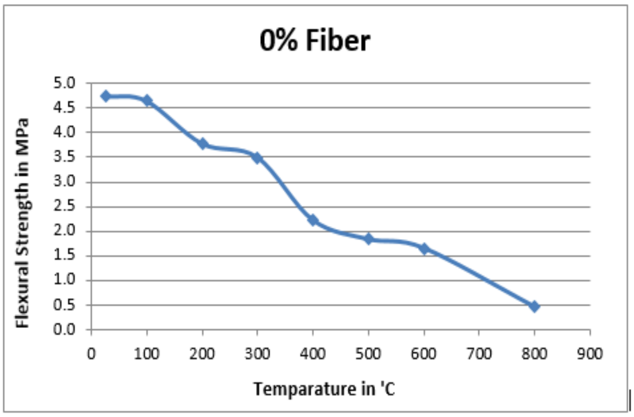

Chart 6.1 0% Fiber

Table 6.3 Variation of Flexural Strength with 1% Steel

Temperature (°C)	Flexural strength (MPa)
27	5.865
100	4.77
200	4.62
300	4.21
400	3.18
500	3
600	2.43
800	1.62

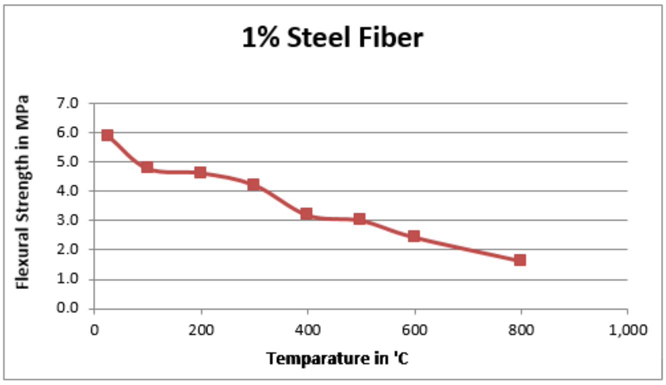

Chart 6.2 1%Steel

Fig 6.2 Test setup

Table 6.4 Load deflection for different specimens at 27 temp

at 27	0% FIBER	1% STEEL
load kN	Deflection mm	Deflection mm
0	0	0
1	0.1	0
2	0.15	0.1
3	2.1	1.2
4	2.9	1.6
5	3.2	1.9
6	3.9	2.2
7	4.3	2.6
8	4.45	2.7
9	4.65	2.9

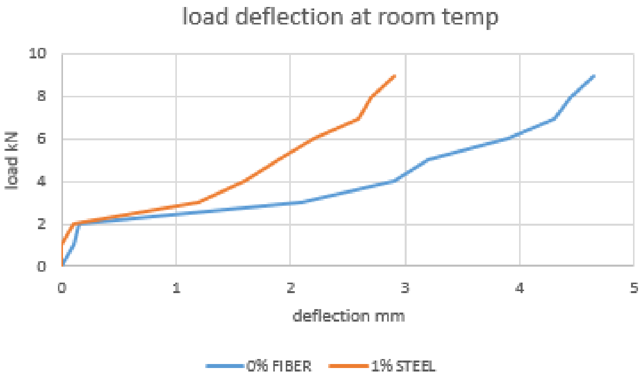

Chart 6.3 load deflection at room temp

Table 6.5 Load deflection for different specimen at 100 temp

at 100	0% FIBER	1% STEEL
load kN	Deflection mm	Deflection mm
0	0	0
1	0.75	0.65
2	1.05	0.96
3	1.15	1.25
4	1.18	1.85
5	1.22	1.96
6	1.26	2.13
7	1.3	2.25
8	1.35	2.4
9	1.38	2.55

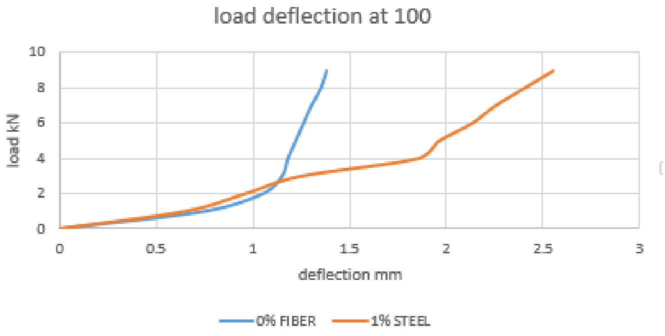

Chart 6.4 load deflection at 100 temp

Table 6.6 Load deflection for different specimen at 200 temp

at 200	0% FIBER	1% STEEL
load kN	Deflection mm	Deflection mm
0	0	0
1	0	0.46
2	0.04	0.72
3	0.46	0.83
4	0.6	0.88
5	0.65	0.95
6	0.74	1.01
7	0.8	1.06
8	0.89	1.1
9		1.14

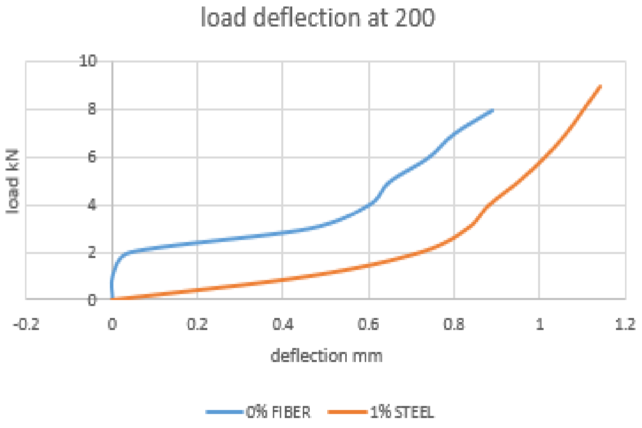

Chart 6.5 load deflection at 200 temp

Table 6.7 Load deflection for different specimen at 300 temp

at 300	0% FIBER	1% STEEL
load kN	Deflection mm	Deflection mm
0	0	0
1	0.6	0
2	0.8	0.1
3	1	0.9
4	1.1	1.2
5	1.1	1.3
6	1.2	1.5
7	1.3	1.8
8	1.3	2
9	1.4	2.2

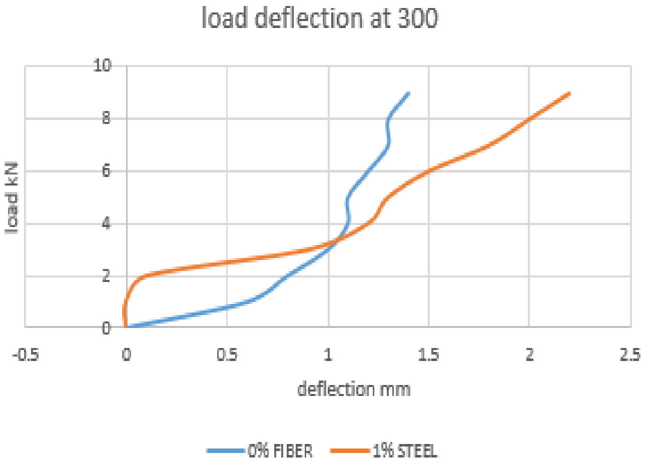

Chart 6.6 load deflection at 300 temp

Table 6.8 Load deflection for different specimen at 400 temp

at 400	0% FIBER	1% STEEL
load kN	Deflection mm	Deflection mm
0	0	0
1	0	0.005
2	0.01	0.0075
3	0.015	0.009
4	0.02	0.015
5	0.025	0.02
6	0.026	0.025
7		0.03
8		0.032
9		0.032

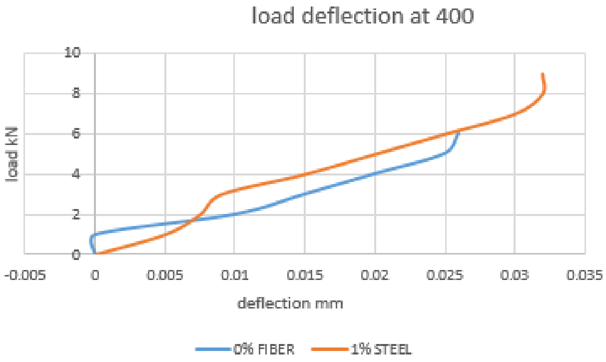

Chart 6.7 load deflection at 400 temp

Table 6.9 Load deflection for different specimen at 500 temp

at 500	0% FIBER	1% STEEL
load kN	Deflection mm	Deflection mm
0	0	0
1	0.1	0.01
2	0.8	0.2
3	0.95	0.55
4	1	0.9
5		1.1
6		1.15
7		1.2

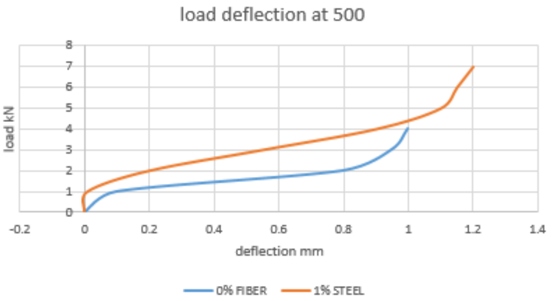

Chart 6.8 load deflection at 600 temp

Table 6.10 Load deflection for different specimen at 600 temp

at 600	0% FIBER	1% STEEL
load kN	Deflection mm	Deflection mm
0	0	0
1	0.1	0
2	1.4	1.05
3	2.2	2
4	2.75	2.35
5		2.7
6		2.85

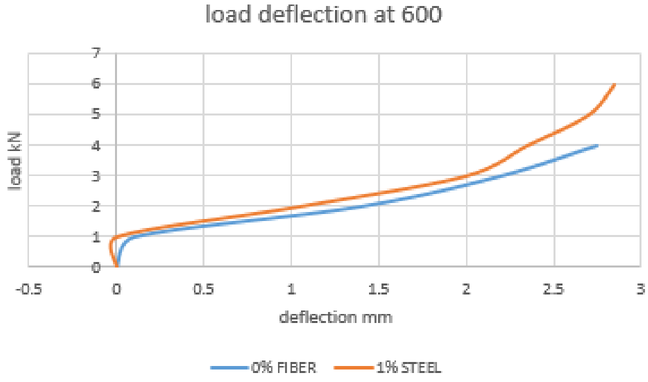

Chart 6.9 load deflection at 600 temp

Table 6.11 Load deflection for different specimen at 800 temp

at 800	0% FIBER	1% STEEL
load kN	Deflection mm	Deflection mm
0	0	0
1	1.9	0.3
2	7	3.6

3		5.6
4		6

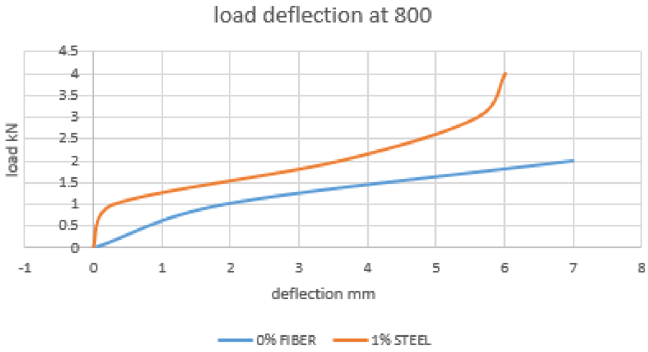

Chart 6.10 load deflection at 600 temp

7. SUMMARY AND CONCLUSION

7.1 Summary

The present investigation work was carried out to find the effect of elevated temperature on steel fiber and polyester reinforced concrete in terms of their residual properties after the specimens were subjected to different temperatures ranging from room temperature, 100˚C upto 600˚C and 800˚C sustained for a period of 2 hours exposure. The residual strength of these beams was found by carrying flexural strength test using universal testing machine of 100 tones capacity. Bending in beams during testing was measured by dial gauge. The results were tabulated and comparison between the specimens of different fiber volume added was inferred.

7.2 Conclusions

1. The physical observations such as the effect on aggregates, the spalling effect, cracks on surfaces can give valuable information regarding the temperature exposure of fiber reinforced concrete.

2. From the results of different sustained temperature duration studies, it can be concluded that the flexural strength reduction of the polyester and steel combination fiber reinforced concrete depends more on the temperature to which it is subjected. As the temperature to which the specimen is subjected to increases, the flexural strength decreases.

3. For 0% Fibers From the results, it is conspicuous that there is a decrease in flexural strength with increase in temperature.

4. For 1% steel Fibers from the results, it is conspicuous that there is a decrease in flexural strength with increase in temperature. In this case the reduction in flexural strength is less between 100 to 300c, whereas temperature increases strength also decreased greatly.

5. For 1% steel and polyester Fibers From the results, it is conspicuous that there is a decrease in flexural strength with increase in temperature. In this case the reduction in flexural strength is gradual for 2hours exposure at 100˚C and 200˚C.flexural strength at 300˚C is very near to strength at room temperature. At 600˚C and 800^{0}c, flexural strength drastically decreased.

6. For room temperature, the strength achieved war greater when compared to other temperatures. 1% steel fiber combination shows less deflection when compared to other combination of fiber. 0% fiber shows more deflection

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