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Self compacting concrete at elevated temperature

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Abstract— ***This experimental study investigates the behavior of Self Compacting Concrete (SSC) exposed to 400^0C, 600^0C and 800^0C elevated temperature consisting fibers as steel fibers and polypropylene fibers. The behavior has studied in terms of compressive strength by casting cubical specimen of SSC M30 grade with 1% and 0.5% of fibers (Steel and Polypropylene fibers) heated for 2 hrs. and 4 hrs. of duration after 7 days of curing. The results of this investigation prove that rise in temperature and its duration decreases compressive strength of specimen accordingly the fibers used in it. The performance of concrete regrets for temperature 800^0C by relating with results of lower temperature of 400^0C. 1% Steel fiber and 0.5% Polypropylene fibers shows significant results in the development of higher compressive strength and improved toughness, at elevated temperatures, the use of steel fibers appears to provide optimum post-cracking behavior.***

Key words—*Compressive strength, Elevated temperature ,Steel fiber, SSC, Polypropylene fiber,*

I. INTRODUCTION

A. General:

Self-compacting concrete, a concrete with high flow ability that can be placed and compacted under its own weight without any external vibration, allows complete filling of formworks along with the complete covering of the reinforcing bars in compact matrix structure. SCC has many advantages that include faster construction, better surface finishes, easier placing, reduction in noise levels and improved durability but it affects when exposed to fire and loses its strength.

The rapidly advancing technology of structural design and fire safety created a need for more precise information on the behavior of structures during fires. The maximum temperature reached during a fire is normally estimated indirectly from the melting of ingredients of concrete. A temperature of 1000ºC to 1100ºC observed during fire in residential buildings for duration mostly found to be in between 1 to 2 hours. For public buildings, temperature rises up to 1100ºC to 1200ºC and the fire duration may exceed 2 to 3 hours in some cases. Still higher temperatures have been observed during fires in industrial buildings and ware houses in which considerable quantities of solid and liquid lubricants are stored. The fire in industrial buildings may last for more than two hours and the temperature may go beyond 1300ºC. Among these temperature of 1000 to 1100ºC during fires which lasted for a duration of 1 to 2 hours has been observed more frequently. Thus, temperature and its duration affects exposed concrete, it chips and flakes known as "spalling"-resulting from the vaporization of water trapped within due to the high temperature. In concrete structure, chips split away from ceilings, walls and supporting pillars, reducing their load bearing capacity and increasing the risk of collapse. performed experimental study on Carbonate, siliceous, and lightweight aggregate concrete and were heated for short duration to temperatures of 200 to 1600° F (93 to 871°C).The lightweight concrete had strength characteristics at high temperatures similar to those of carbonate concrete. At temperatures above 800°F (427°C), the siliceous aggregate concrete had lower strength than the other concretes [1]. HSC lost its mechanical strength in a manner similar to that of NSC. The range between 400 and 800°C was found to be critical to the strength loss[2].

The relationship between occurrence of explosive spalling and residual mechanical properties of fiber such as Steel fiber, polypropylene fiber, and hybrid fiber, toughened high performance concrete exposed to high temperatures. After exposure to high temperatures ranged from 200 to 800 °C, the residual strength was decreased by exposure to high temperatures over 400 °C, residual fracture energy was significantly higher than that before heating. Incorporating hybrid fiber seems to be a promising way to enhance the resistance of concrete to explosive spalling [3].

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This study of using various fibers concluded that the use of fibre cocktail reinforced SCHPC material can be very effective in reducing thermal stress and in improving composite effect of hybrid fibres on the post crack behaviour during heating process at high temperature[4].

B. Scope of Study:

The efficiency of SCC can be increase by introducing of fibers like polypropylene fibers, steel fibers and glass fibers, further enhance their toughness, tensile strength, resistance to crack propagation thereby improving the durability properties. The effects of fibers were qualified based on the fiber volume, length, and its aspect ratio, other properties of fibers such as shape and surface roughness are also found to be important. This work contributes for experimental evaluation of compressive strength of SCC with fibers exposed to elevated temperature up to 800^0C for 2 hrs. and 4 hrs. of heating duration. Steel fibers and Polypropylene fibers are used for this demonstration in two different percentage as 0.5% and 1% as steel fibers consists high elastic modulus and stiffness and Polypropylene fibers allow the water vapour to escape without increasing the internal pressure, so the concrete structure remains intact.

II. EXPERIMENTAL WORK

Concrete exposed to temperature higher than 300ºC may experience loss in strength. High strength concrete is more susceptible to explosive spalling when exposed to temperatures above 300ºC. This research was designed to study the behavior of self-compacting concrete subjected to elevated temperatures by experimental investigation on compressive strength with Polypropylene fibers and steel fibers.

A. Program Work

To modify the concrete to such a scale that it would provide higher strength even at tremendous temperature and concrete should be self compacting for the ease of placement at congested reinforcement. To reinforce our idea we have used two different fibers (steel and polypropylene) at three different temperature (400,600 and 800 degree Celsius) for two different time intervals (2 and 4 hours) in muffled furnace.

B. Material Properties:

Characteristic compressive strength (fck) = 30Mpa
Packing factor = 1.04
Specific gravity of cement (Gc) = 3.12
Specific gravity of fine aggregate (Gfa) = 2.61
Specific gravity of coarse aggregate (Gca) =2.68
Specific gravity of water (Gw) = 1.0
Bulk density of FA (Wfa) =1594 Kg/m3
Bulk density of CA (Wca) =1264 Kg/m3
The volume ratio of fine aggregate = 0.54
Super plasticizer (sp.dosage) =0.8 %
Air content = 1.5%
Monofilament type Polypropylene fiber of length 30mm to 50mm.

Fig. 2.1 Polypropylene fibers

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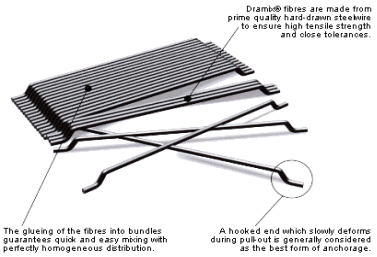

Fig. 2.2 Steel Fibers

C. Mix Proportion:

Following mix proportion were adopted during the execution, obtained by trial and error method.

Material	Cement	Sand (fa)	Aggregate (ca)	Water
Kg/m^3	430	700.9	524.60	180.6
Ratio	1	1.63	1.22	0.42

D. Execution of work:

The fibrous concrete has been classified into two categories depending upon the two types of fiber viz. steel, and polypropylene. All the two fiber have been used in two proportions viz. 1% and 0.5%.. 2 cubes of each proportion is casted for three different temperatures as 400^0C, 600^0C and 800^0C for two different time as 2hrs and 4 hrs. Water cooling adopted after heating in muffle furnace. For each temperature there were two cubes, average of both were taken to avoid any defect in analysis. For the better performance we have used superplasticizer in concrete to enhance its flow ability.

E. Performance Analysis:

It was reported that compressive strength of SCC decreased with increase in temperature. It was found that grade of concrete had an effect on the strength loss of concrete, especially in the temperature range below 400°C. Addition of fibers into concrete improves the overall ductility of the concrete imparting toughness, greater tensile strength, and resistance to fatigue, impact, blast loading and abrasion. The performance of each modified concrete were analyzed based on compressive strength of concrete.

Figure 2.4 Muffle furnace

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Fig. 2.5 Removal of Cube from Muffle Furnace

III. RESULTS AND DISCUSSION:

Following are the results represented in terms of compressive strength and its percentage reduction as temperature increases from 400^0C to 800^0C

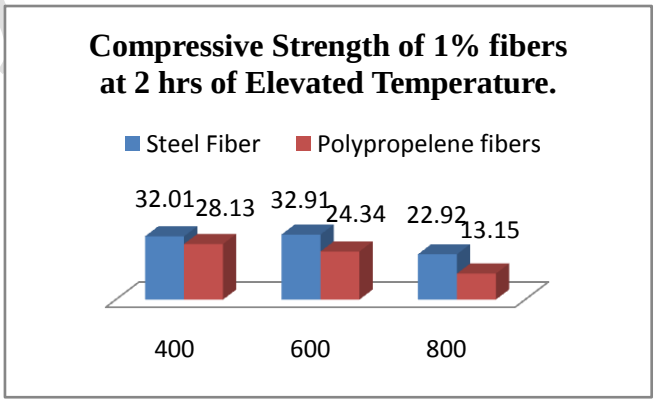
A. Compressive Strength:

a) 1% Fibers for elevated temperature upto 2 hrs:

Table No. 3.1 and Figure No. 3.1 shows tabular and graphical representation of average compressive strength of M30 grade concrete with 1% steel fiber and polypropylene fiber respectively at 400℃, 600℃ and 800℃ for 2 hours, after 7 days curing.

Table No. 3.1 Compressive Strength of 1% fibers for 2 hrs of elevated tempretaure

Sr. No.	Temperature	Steel Fiber	Polypropelene Fiber
1	400	32.01	28.13
2	600	32.91	24.34
3	800	22.92	13.15



Graph No. 3.1 Compressive Strength of 1% fibers for 2 hrs of elevated temperature

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Above observations were noted for 1% fibers and exposed to elevated temperature for 2 hrs after 7 days of curing. It shows, for steel fiber, compressive strength of concrete cubes exposed for 400^0C temperature as 32.01 N/mm^2 but if temperature increased upto 800^0C for the same the value of strength reduced to 22.92 N/mm^2. and for the same strength of Polypropylene fiber dropped from 28.13 N/mm^2 to 13.15 N/mm^2.

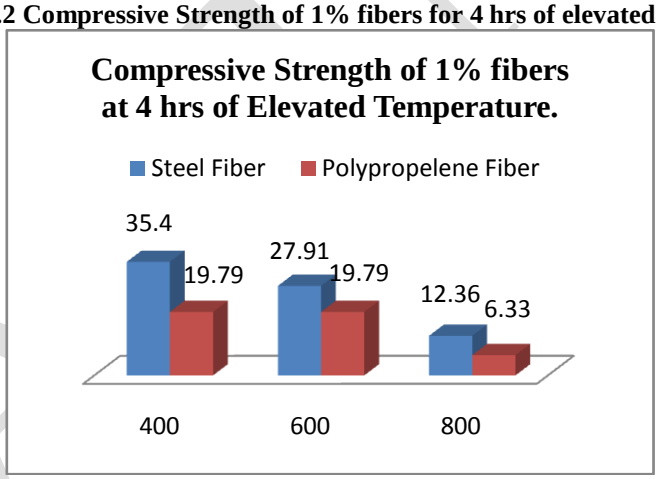
b) 1% Fibers for elevated temperature upto 4 hrs

Table No. 3.2 and Figure No. 3.2 shows tabular and graphical representation of average compressive strength of M30 grade concrete with 1% steel fiber and polypropylene fiber respectively at 400°C, 600°C and 800°C for 4 hours, after 7 days curing.

Table No. 3.2 Compressive Strength of 1% fibers for 4 hrs of elevated temperature

Sr. No.	Temperature	Steel Fiber	Polypropelene Fiber
1	400	35.4	19.79
2	600	27.91	19.79
3	800	12.36	6.33

Graph No. 3.2 Compressive Strength of 1% fibers for 4 hrs of elevated temperature



Above results shows the readings noted for SCC with 1% fibers and exposed to elevated temperature for 4 hrs after 7 days of curing. During this experiment it was observed that, concrete with steel fiber exposed for 400^0C temperature achieved compressive strength as 35.4 N/mm^2 and for Polypropylene fiber its value dropped from 19.79 N/mm^2 to 6.33 N/mm^2.

c) Comparison of Compressive Strength with 1% Fibers (Steel, Glass and Polypropylene)for elevated temperature 2 hrs and 4 hrs:

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Table No. 3.3 Comparison of Compressive Strength with 1% Fibers elevated temperature 2 hrs and 4 hrs

Temperature	Steel Fiber		Polypropylene Fiber	
	2 Hrs	4 Hrs	2 Hrs	4 Hrs
400	32.01	35.4	28.13	19.79
600	32.91	27.91	24.34	19.79
800	22.92	12.36	13.15	6.33

Table above represents the comparative study of compressive strength obtained after using 1% fibers in SCC of grade M30 exposed for two different time duration as 2 hrs and 4 hrs. It shows reduction in compressive strength as duration of exposure temperature increases.

d) 0.5% Fibers for elevated temperature upto 2 hrs

Table No. 3.4 and Figure No. 3.3 shows tabular and graphical representation of average compressive strength of M30 grade concrete with 0.5% steel fiber and polypropylene fiber respectively at 400℃, 600℃ and 800℃ for 2 hours, after 7 days curing.

Table No. 3.4 Compressive Strength of 0.5% fibers for 2 hrs of elevated temperature

Sr. No	Temperature	Steel Fiber	Polypropelene Fiber
1	400	29.2	32.705
2	600	32.44	25.79
3	800	17.33	12.46

Graph No. 3.3 Compressive Strength of 0.5% fibers for 2 hrs of elevated temperature

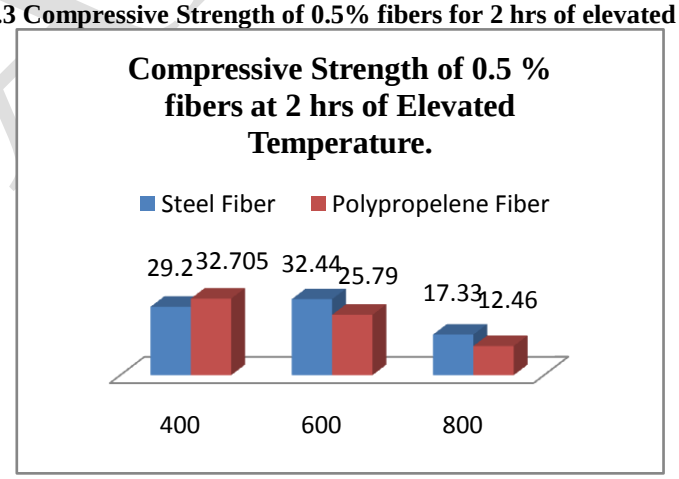

Table and graph above shows the observation obtained for 0.5% fibers and exposure for 2 hrs of elevated temperature for M30 grade SCC. In this case, strength for 400^0C temperature were noted as 29.2 N/mm^2, if further increase in temperature upto 800^0C strength dropped to 17.33 N/mm^2 for steel fibers. Use of 0.5%

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Polypropylene fiber in M30 SCC, the noted value of compressive strength was 32.705 N/mm^2 under 400^{0}C and decreased to 12.46 N/mm^2 for temperature 800^{0}C.

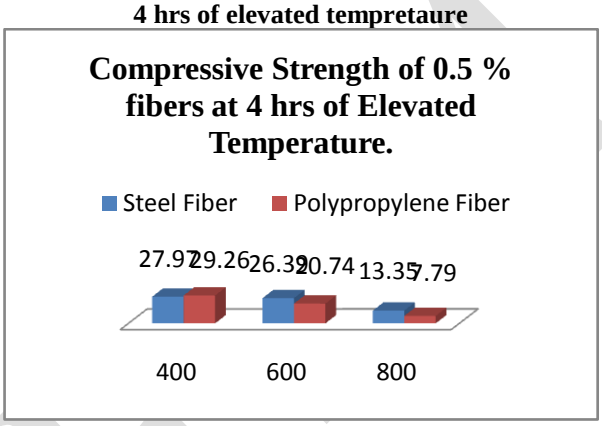
e) 0.5% Fibers for elevated temperature upto 4 hrs

Table No. 3.5 and Figure No. 3.4 shows tabular and graphical representation of average compressive strength of M30 grade concrete with 0.5% steel fiber and polypropylene fiber respectively at 400℃, 600℃ and 800℃ for 2 hours, after 7 days curing.

Table No. 3.5 Compressive Strength of 0.5% fibers for 4 hrs of elevated temperature

Sr No	Temperature	Steel Fiber	Polypropylene Fiber
1	400	27.97	29.26
2	600	26.39	20.74
3	800	13.35	7.79

Graph No. 3.4 Compressive Strength of 0.5% fibers for 4 hrs of elevated tempretaure



Above table and figure are the tabular and graphical representations of result obtained after using 0.5% of fibers in SCC of M30 grade under elevated temperature of 400^0, 600^0 and 800^0 for 4 hrs. It shows falling in strength of concrete as the temperature increases, it is observed for steel fibers strength falls from 27.97 N/mm^2 to 13.35 N/mm^2, and for polypropylene fibers it decreases from 29.26 N/mm^2 to 7.79 N/mm^2.

f) Comparison of Compressive Strength with 0.5% Fibers (Steel, Glass and Polypropylene)for elevated temperature 2 hrs and 4 hrs:

Table No. 3.6 Comparison of Compressive Strength with 0.5% Fibers elevated temperature 2 hrs and 4 hrs

Sr No	Temperature	Steel Fiber		Polypropylene Fiber	
		2 Hrs	4 Hrs	2 Hrs	4 Hrs
1	400	29.2	27.97	32.7	29.26
2	600	32.44	26.39	25.79	20.74
3	800	17.33	13.35	12.46	7.79

Table above shows the change in compressive strength as duration of exposure of elevated temperature increases. This change in values shows falling in strength as duration increases for SCC of grade M30 with 0.5% fibers.

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IV. CONCLUSION:

Following conclusions can be drawn from the study work performed experimentally on cubical specimen of M30 grade SCC exposed to elevated temperature from 400^0C to 800^0C in presence of steel fibers and polypropylene fibers in two different ratios.

1. For 2 hrs of heating to specimen with 1% fibers shows the reduction in compressive strength in polypropylene fiber and it is also observed that strength of specimen with steel fibers heating upto 800^0C for duration of 2 hrs reduced by 28.46% compare to specimen in 400^0C temperature and 53.25% decrease in strength for polypropylene fibers used in same concrete mix instead steel fibers.
2. Increasing in duration from 2 hrs to 4 hrs also suffers compressive strength of same grade of concrete with same percentage of fibers. Exposure to elevated temperature upto 800^0C for 4 hrs decrease the performance of concrete by 64.80% and 68.01% for steel and polypropylene fibers compare to the strength of specimen under 400^0C temperature for same duration of 4 hrs.
3. Comparing the effect of type of fibers in concrete, 1% steel fiber gives the better performance compare to polypropylene fibers used in same percent.
4. By reducing percentage of fibers from 1% to 0.5% for 2 hrs of heating for 400^0C, 600^0C and 800^0C shows compressive strength dropped by 40.65% and 62.38% as temperature increases from 400^0C to 800^0C in presence of steel fibers and polypropylene fibers respectively.
5. 0.5 % Polypropylene fibers in concrete exposed to 400^0C temperature for 2 hrs shows better performance compare to steel fibers
6. 0.5% Steel fibers shows highest resistance when heated for 4 hours and least in polypropylene fiber.
7. Addition of fibers to self-compacting concrete improves compressive strength of the mix.
8. The tested SCFRC mixtures with its different constitutions did not show a pronounced negative effect on the maturity of concrete, and leads to a higher strength gain as well.
9. After observing all parameters we can say that steel fiber works better at all three temperatures.

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