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Fiber Reinforced High Performance Concrete at Elevated Temperature

Fahmeed Shafi[1] and Harpal Singh[2]

[1]*Student (PG), Guru Nanak Dev Engineering College Ludhiana*
[2]*Professor (Faculty), Department of Civil Engineering, Guru Nanak Dev Engineering College Ludhiana*
E-mail: fahmeedshafi@gmail.com, hpsbhoday@yahoo.com

Abstract—*Consumption of fiber reinforced concrete increases tremendously as it has been found to improve strength, ductility, toughness and durability of the structures. The main objective of this experimental investigation is to find the effect on flexural and compressive strength of High Performance Concrete (HPC) after exposing to elevated temperature and find out the optimum combination of fibers for getting best response. HPC were prepared in batches, each batch were divided into five sub batches with varied percentage of steel to poly propylene fibers of (100-0), (75-25), (50-50), (25-75) and (0-100) both at 1% and 1.25% of fiber proportion from the volume of concrete. After exposing the specimens to elevated temperature of 500^0C the results shows that both flexural strength and compressive strength declines. The more the percentage of steel fibers in concrete batch the lesser is the decrement in strength both at 1% and 1.25%. Out of five concrete batches ST-PP (75-25) both at 1% and 1.25% volume fraction proves the optimum dosage of fibers with only 13% loss of strength compared to the target strength of 31.6 MPa at elevated temperature of 500^0C.*

Keywords: *HPC, Steel Fibers and Poly Propylene Fibers, Elevated Temperature, Compressive Behaviour and Flexural Behaviour.*

1. INTRODUCTION

As from many researches it has been observed that fiber reinforced concrete exhibits high flexural strength, compressive strength and split tensile strength [Drzymala, 2017]. Once the fiber reinforced concrete gets exposed to elevated temperature by means of fire or prolonged high temperature the mechanical properties of concrete got affected [Aminuddin jameran, 2015]. It has also been observed lot of physical and chemical changesoccurs in concrete and one of the most serious effects seen in concrete is explosive spalling which results the deterioration of concrete [Poon. S.Z 2004]. The serious effect of spalling in concrete due to elevated temperature can be controlled by addition of poly propylene fibers according to previous studies although some negative performances like decrease in strength occurs [Abdullah, 2013]. The concrete with accumulation of steel and poly propylene loses its water content and becomes brittle after exposed to elevated temperature. The current experimental investigation is to determine the effect of elevated temperature on flexural strength and compressive strength. The water cement ratio used in designing the mix of M25 grade was 0.40 and also the super plasticizer accompanied was glenium (1% by mass of cementitious material) which helps to disperse the cement particles in the mix in order to promote mobility.

2. Investigational Program

Experimental investigation was conceded to accomplish the objectives of study. Grade of M25 was prepared with coarse aggregates of size 16- 20 mm, fine aggregates of zone II and Glenium as a superplastisizer. High performance concrete were prepared in batches, each batch was divided into five sub batches with varied percentage of steel to poly propylene fibers of (100-0), (75-25), (50-50),

(25-75) and (0-100) both at 1% and 1.25% of fiber proportion from the volume of concrete. After exposing the specimens to elevated temperature of 500^0C the results shows that both flexural strength and compressive strength declines. Compressions testing machine of capacity 2000kN and Universal testing machine of capacity 100kN were utilized for determining compressive strength and flexural strength respectively.

3. Compression and Flexural Testing

Cubes of (150×150×150)mm and Prisms of (100×100×500) mm size following 28 days of curing are tested against compression and flexure respectively after exposed to elevated temperature of 500^0C with average rate of heating 6^0C/min in an electrical furnace with digital temperature controller. Flexural testing was accompanied with Universal Testing Machine (UTM) with rate of loading 0.05mm/min. Apart from determining compressive and flexural strength the load displacement data were recorded from Linear Variable Differential Transducer (LVDT) in cubes and from UTM in beams. The whole investigation was carried out on 70 samples, 35 cubes and 35 beams made of concrete with different percentage of ST-PP fibers. Figure 1 given below shows the test setup for compression and Figure 2 depicts the arrangement of samples in electrical furnace.

Figure 1: Compression test Figure 2: Electrical Furnace

4. Materials

High Performance Concrete (HPC) of grade of M25 has been produced by using the Portland Pozzolana Cement (PPC), coarse aggregates of size between 16 mm to 20 mm and fine aggregates of zone II. The mix design was prepared as per IS 10262 with water cement ratio of 0.40 and the addition of (Glenium) water reducing admixture which is poly carboxylate based (PC). Table 1 to Table 3 below depicts the properties of Cement, aggregates and Fibers respectively. Apart from these basic materials of concrete two different types of fibers steel and poly propylene were accommodated with varying percentages.

Table 1: Physical Properties of Cement

S. No.	Physical properties	Test Result	Required value as per (IS 1489-1991) part 1
1	PPC	-	-
2	Initial setting time, (Min.)	30	>30 min
3	Final setting time, (Min.)	345	≤ 10 hours
4	Specific gravity	3.03	3.0 -3.15

Table 2. Physical Properties of Aggregates

S. No	Tests	Fine Aggregates	Coarse Aggregates
1	Specific gravity	2.62	2.68
2	Fineness Modulus (%)	2.63	6.98
3	Water Absorption (%)	1	0.5

Table 3. Characteristics of Fibers

S No.	Materials	Density (Kg/m^3)	Geometry and Size	Melting Point (^{0}C)
1	Steel fibers	7850	L_f = 60 mm, Crimpled Diameter = 0.8 mm L/d = 75	-
2	Poly propylene fibers	946	L_f = 12 mm, Straight Diameter = 18 micron	160 - 170

5. Steel Fibers and Poly Propylene Fibers

To overcome the problems of low ductility, tensile strength and resistance to cracking of plain concrete, different types of fibers are utilized. As it has been observed that the accumulation of steel fibers enhances the static and dynamic properties of concrete. Addition of steel fibers increases or doubles the energy absorption capacity of unheated concrete and after elevated temperature it helps in retaining the strength and controlling the catastrophic failure. While as poly propylene fibers are very much beneficial to control the risk of spalling in concrete by creating the micro channels which are more permeable and allows the outward migration of vapours produced and hence relivesstresses. Figure 3 and Figure 4 below represents the ST and PP fibers employed in study.

Figure 3: Steel fibers

Figure 4: Poly propylene fibers

6. Results

6.1. Compressive Strength Results Table 4 depicts the results of compressive strength of cubes of size (150×150×150) mm at 1% volume fraction after exposed to elevated temperature of 500^{0}C including the control mix.

Table 4. Compressive strength test results at 1%

Concrete batch (ST-PP)	Temperature (^{0}C)	Compressive Strength (MPa)
Control (0-0)	500	14.86
(100-0)	500	25.52
(75-25)	500	24.85
(50-50)	500	18.94
(25-75)	500	17.47
(0-100)	500	14.96

Table 5. Compressive strength test results at 1.25%

Concrete batch (ST-PP)	Temperature (^{0}C)	Compressive Strength (MPa)
Control (0-0)	500	14.86
(100-0)	500	29.54
(75-25)	500	24.29
(50-50)	500	18.23
(25-75)	500	10.94
(0-100)	500	8.67

6.2 Flexural Strength Test Results

Table 6 depicts the flexural strength results of prisms with varying percentages of steel to poly propylene fibres of size (100× 100× 500) mm at

1% volume fraction after exposed to elevated temperature.

Table 6. Flexural strength test results at 1%

Concrete batch (ST-PP)	Temperature (^{0}C)	Compressive Strength (MPa)
Control (0-0)	500	0.75
(100-0)	500	2.45
(75-25)	500	2.21
(50-50)	500	1.95
(25-75)	500	1.82
(0-100)	500	0.58

Table 7: Flexural strength test results at 1.25%

Concrete batch (ST-PP)	Temperature (^{0}C)	Compressive Strength (MPa)
Control (0-0)	500	0.75
(100-0)	500	2.53
(75-25)	500	2.23
(50-50)	500	1.50
(25-75)	500	0.50
(0-100)	500	0.45

6.3. Load-Displacement-Curves

Figure 5shows the Load – Displacement curves for prism of steel to polypropylene dosage (75-25) at 1% volume fraction after exposed to elevated temperature obtained from universal testing machine of capacity 100kN and Figure 6 shows Load-Displacement curve of (75-25) at 1% obtained from compression testing machine using LVDT.

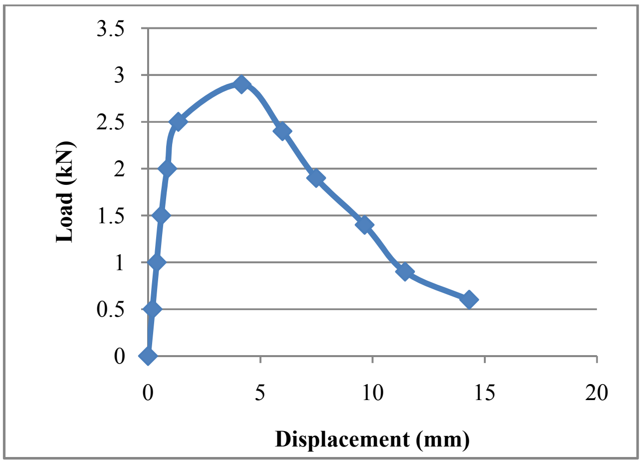

Figure 5: (ST-PP) 75-25 at1%

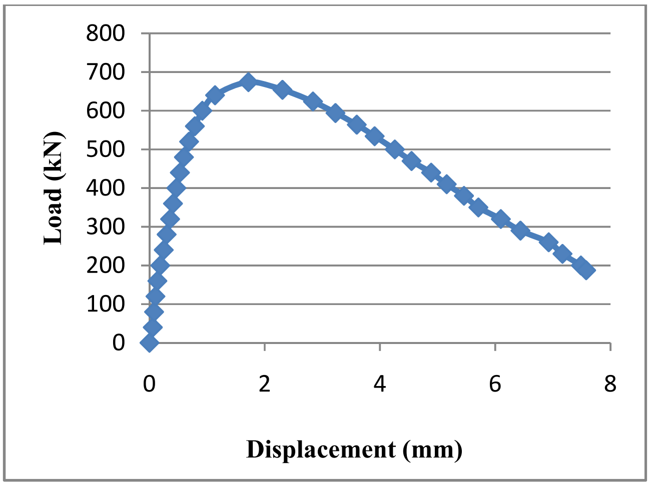

Figure6: (ST-PP) 75-25 at 1%

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8. Conclusions

It is clear from the results that both flexural and compressive strength declines followed by elevated temperature which makes the structure brittle and hence deteriorates. Although addition of fibers proves beneficial, addition of steel fibers increases the toughness and so prevents it from sudden failure and addition of PP fibers reduces the spalling effect. It is evident from the experimental observations that ST-PP (75-25) proves optimum dosage of combined fibers than the remaining batches both at 1% and 1.25%.

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