Journal of Architectural Environment & Structural Engineering Research
https://ojs.bilpublishing.com/index.php/jaeser

ARTICLE

Mechanical Properties of Polypropylene Fiber Reinforced Concrete under Elevated Temperature

Vikas Patel* **Brijesh Singh** **P N Ojha** **Sahara Adhikari**

National Council for Cement and Building Materials, Ballabgarh, Haryana, India

ARTICLE INFO

Article history
Received: 29 May 2021
Accepted: 25 June 2021
Published Online: 29 June 2021

Keywords:
High strength concrete
Fiber reinforced concrete (FRC)
Polypropylene fibers
Residual mechanical properties
Spalling resistance

ABSTRACT

Apart from many advantages, High Strength Concrete (HSC) has disadvantages in terms of brittleness and poor resistance to fire. Various studies suggest that when polypropylene (PP) fibers are uniformly distributed within concrete, they play an active role in improving spalling resistance of concrete when exposed to elevated temperature while having no adverse effect on its mechanical properties. Therefore, there is a necessity to quantify the effect of the addition of polypropylene fibers in terms of the fiber dosage, the strength of the concrete, and the residual mechanical properties of fiber-reinforced concrete under exposure to high temperature from fire.

The study was carried out on three water/cement (w/c) ratios (0.47, 0.36 & 0.20) using granite aggregate for determining short term mechanical properties of Polypropylene fiber reinforced concrete in comparison to control mix. The experimental program includes 100 × 200 mm & 150 x 300 mm cylinders with fiber volume of 0.5%, that were subjected to temperatures exposures of 400 °C and 600 °C for durations of 1 hour. From the results, it was observed that no significant enhancement in mechanical properties such as modulus of elasticity, Poisson's ratio, split tensile strength, flexural strength, and compressive strength was observed at room temperature and at elevated temperatures.

1. Introduction

With the advancement of concrete technology, high-strength concrete has been used in many concrete structures across the globe. HSC offers higher strength and durability as compared to Normal Strength Concrete (NSC) [1-3]. The major advantage of the addition of fibers to concrete is to transform its brittle behavior into a pseudo ductile material. Fibers in concrete cause gradual failure by arresting micro-cracks presents in the concrete. The fibers from waste materials may be used for the sustainable construction of structural units with cement mortar composites, especially in developing countries. Various studies on mechanical properties of concrete incorporating different types of fibers like steel, carbon, glass, and synthetic fibers have been done in the past to understand the behavior of fiber-reinforced concrete.

Concrete with randomly distributed fibers is defined as Fiber-reinforced concrete (FRC). Fibers dispersed and distributed randomly during mixing results in improved concrete properties in all directions. From the test results of different types of fiber materials such as steel, carbon,

**Corresponding Author:*
Vikas Patel,
National Council for Cement and Building Materials, Ballabgarh, Haryana, India;
Email: vikas.patel299@gmail.com

 DOI: https://doi.org/10.30564/jaeser.v4i2.3296

glass, plastic, polypropylene, nylon, and cotton, American Concrete Institute's Committee 544 [4] classified FRC into four different groups based on the fiber materials namely steel fiber reinforced concrete (SFRC), glass fiber reinforced concrete (GFRC), synthetic fiber reinforced concrete (SNFRC), and natural fiber reinforced concrete (NFRC). Synthetic fibers such as polyester, acrylic, polyethylene, and polypropylene are further subdivided based on the diameter size of fibers into micro-synthetic fibers (for diameter less than 0.30 mm) and macro-synthetic fibers (for diameter greater than 0.30 mm).

Apart from steel fibers, polypropylene fibers are widely used in the market. However, the elastic and strength properties of both fibers vary significantly. For the last many years, steel fibers were generally used in concrete roadwork and sprayed concrete applications. The coming of polypropylene fibers has introduced the possibility of having a high-performance and more sustainable product for the improvement of concrete properties. Polypropylene fibers have better durability as corrosion does not take place in the case of plastic. As it weighs about one-fifth of equivalent steel fiber, it increases the ease of handling. Research on various aspects was done in the past to understand the mechanical behavior of fiber-reinforced concrete and continued till date to recognize the usage of fibers in concrete, and the fibers themselves. [5] Khajuria and Balaguru carried out a study on polypropylene fiber reinforced concrete and concluded that if more water is added to improve the workability of FRC, a reduction in compressive strength may occur. This reduction in compressive strength should be attributed to additional water or due to an increase in entrapped air and not to the fiber addition in the matrix. [6] Alhozaimy, A.M., carried out experimental investigations on compressive, flexural, and impact strength for different binder compositions after adding low volume fractions of polypropylene fibers in concrete. No significant effect on compressive (or) flexural strength was observed upon the addition of fibers, while flexural toughness and impact resistance values were increased. Positive interactions between fibers and pozzolans were also detected.

[7] Bentur et al concluded that the addition of polypropylene fibers does not have a significant effect on the direct tensile cracking strength. However, for volume replacements in the range of 0.33-0.5%, the addition of macro-synthetic polypropylene fibers resulted in 10-15% increase in splitting tensile strength. Further, some studies show that polypropylene fibers can improve the residual compressive strength of concrete after fire exposure. While the presence of different dosages of polypropylene fibers has no significant improvement in residual compressive strength at 200 °C and 400 °C, but beyond 600 °C it considerably increases the residual compressive strength of concrete. Moreover, some studies show that compressive strength of the concrete with polypropylene fibers when exposed to temperature up to 400 °C is higher than the concrete without fibers [8-10]. Thus, past studies show mixed results on the residual mechanical properties of polypropylene FRC.

The mechanical properties of FRC get affected when exposed to heat which can come from different sources including fire exposure and continuous high temperature on the exposed surface. Many Researchers have observed explosive spalling which often results in serious deterioration of the concrete. Continuous pressure is a build-up due to the vaporization of evaporable water which can cause serious damage or even spalling of the concrete. This excessive pressure could be released by the presence of voids in the concrete matrix. To reduce the risk of deterioration and spalling, previous studies suggest that the addition of fibers in concrete such as polypropylene and steel can improve sufficient fire protection. The main parameters that determine the effect of polypropylene fibers are the initial moisture and the rate of heating of the concrete. Therefore, it is very important to quantify the effectiveness of these fibers in terms of the fiber dosage, grade of concrete, and most importantly the residual mechanical properties of FRC after exposure to high temperature from fire.

In the present study, three water/cement (w/c) ratios (0.47, 0.36 & 0.20) using granite aggregates were studied for determining short-term mechanical properties of Polypropylene fiber reinforced concrete in comparison to the control mix. Further, the experimental program includes concrete specimens with polypropylene fiber volume of 0.5%, that were subjected to temperatures exposures of 400 °C and 600 °C for durations of 1 hour. For uniform distribution of PP fibers, dry concrete materials were mixed firstly, and then the fibers were added to the dry mixture to avoid breaking of the fibers. From each mixture, for compressive strength, modulus of elasticity and poisons ratio at room temperature concrete cylinder (150 mm dia. and 300 mm height) specimens were cast and for split tensile strength test and for compressive strength test each at the room, 400 °C, 600 °C and 800 °C temperatures concrete cylinders (100 mm dia. and 200 mm height) were cast. The study was carried out on only one fiber dose which was selected based on the optimum dosage from literature. Also, fibers were added to the concrete mixture to avoid explosive failure in the case of high-strength concrete under elevated temperatures. Further, studies using different

DOI: https://doi.org/10.30564/jaeser.v4i2.3296

fiber doses can be carried out which may result in higher residual mechanical properties after exposure to elevated temperatures.

2. Concrete Ingredients

2.1 Materials

● Cementitious Material

Ordinary Portland cement (OPC 53 Grade) with fly ash and silica fume was used The 3 days, 07 days, and 28 days compressive strength of cement were 36.00 N/mm^2, 45.50 N/mm^{2,} and 57.50 N/mm^2 respectively. The physical and chemical properties of cement, fly ash, and silica fume are given in Table 1.

Table 1. Physical, Chemical and Strength Characteristics of Cementitious Material

Characteristics		OPC Cement	Silica Fume	Fly Ash
Physical Tests:				
Fineness (m^2/kg)		322	21980	390
Specific gravity		3.15	2.25	2.28
Chemical Tests:				
Loss of Ignition (LOI) (%)		1.52	1.16	0.5
Silica (SiO_2) (%)		20.41	95.02	61.25
Iron Oxide (Fe_2O_3) (%)		3.86	0.80	5.9
Aluminium Oxide (Al_2O_3)		5.04		24.67
Calcium Oxide (CaO) (%)		60.92		2.06
Magnesium Oxide (MgO) (%)		4.77		0.66
Sulphate (SO_3) (%)		1.88		0.28
Alkalies (%)	Na_2O	0.58	0.73	0.07
	K_2O	0.63	2.96	1.41
Chloride (Cl) (%)		0.04		0.008
IR (%)		1.21		

Aggregates

Natural river sand was used as fine aggregate conforming to Zone II as per IS: 383. Crushed aggregate was used as coarse aggregate with 20 mm maximum nominal size. The physical properties of coarse and fine aggregates are given in Table 2. The quality of both coarse and fine aggregate was fair. The silt content by the wet sieving method in fine aggregate was 0.70 percent.

o Water: Water conforming to the requirements of construction water as per IS: 456-2000 was used.

o Admixture: For HSC with w/c ratio of 0.20 and 0.36 Polycarboxylic group based superplasticizer was used while for NSC with w/c ratio of 0.47 Naphthalene based superplasticizer was used. Superplasticizers were complying with the requirements of IS: 9103-1999.

o Polypropylene fiber (PP): Polypropylene (PP) is classified as a thermoplastic polymer that can be used for a variety of applications that is produced by chain-growth polymerization from monomer propylene. The physical properties of the polypropylene fiber are given in Table 3.

Table 2. Properties of Aggregates

Property		Granite		Fine Aggregate
		20 mm	10 mm	
Specific gravity		2.82	2.81	2.65
Water absorption (%)		0.33	0.31	0.8
Sieve Analysis Cumulative Percentage Passing (%)	20mm	98	100	100
	10 mm	2	69	100
	4.75 mm	0	2	97
	2.36 mm	0	0	86
	1.18 mm	0	0	70
	600 µ	0	0	38
	300 µ	0	0	12
	150 µ	0	0	3
	Pan	0	0	0

Table 3. Properties of Polypropylene fiber

Properties	Value
Cut length (mm)	12
Effective diameter (micron)	25-40
Specific gravity	0.90-091
Melting point (°C)	160-165
Elongation (%)	20-60
Alkaline stability	Very good
Young's modulus (MPa)	>4000

2.2 Mix Design Details

In this study, the three different mixes with w/c ratio 0.47, 0.36 & 0.2 using granite aggregate were studied for short-term mechanical properties of HSC. The slump was kept in the range of 75-100 mm for the fresh concrete. The optimum dosage of superplasticizer for the desired workability was achieved by conducting several trials based on the slump cone test. The mix design details for concrete mixes are given in Table 4. Necessary adjustments were made in mixing water for correction of aggregate water absorption. Pan type of concrete mixer was used for the preparation of the concrete mixes. The moulds were painted with mineral oil and then casting was done in three different layers with each layer compacted on a vibration table to minimize air bubbles and voids. The specimens were demoulded from the moulds after 24 hours. The laboratory conditions were maintained at 27±2 ^{o}C and relative humidity 65% or more and thereafter were cured in temperature-controlled curing tanks. The specimens were tested in saturated surface dried condition.

 DOI: https://doi.org/10.30564/jaeser.v4i2.3296

Table 4. Concrete Mix Design Details for the study done

w/c	Total Cementitious Content [Cement C + Flyash (FA) + Silica Fume (SF)] (Kg/m^3)	Water Content (Kg/m^3)	Admixture dosage % (by weight of Cement)	% Fine Aggregate (by weight)	Compressive Strength of concrete (28-Days) (N/mm^2)
0.47	**362** (290+72+0)	170	1.00	35	45.72
0.36	**417** (334+83+0)	150	0.45	39	68.57
0.20	**750** (548+112+90)	150	1.75	35	97.76

2.3 Optimum Dosage of Polypropylene Fiber

Shihada [11] examined the impact of polypropylene fibers on the fire resistance of concrete with 0%, 0.5%, and 1% of polypropylene by volume, by heating concrete specimens at 200 °C, 400 °C, and 600 °C for the duration up to 6 hours. It was concluded that the compressive strength of concretes with polypropylene fibers were higher than those without polypropylene fibers. Further, it was concluded that for concrete mixes with 0.5% polypropylene fibers, the residual compressive strength during the heating was significantly improved. The loss in compressive strength was about half when polypropylene fibers were used as compared to the concrete without fibers for a temperature exposure of 600°C for 6 hours duration. Kamlesh S.Dalal [12] et al used 6 mm polypropylene fibers and results show about a 4% increase in compressive strength at 0.50% polypropylene fiber by weight of cement.

Anthony Nkem Ede et al [13] studied the effects of micro synthetic polypropylene fiber on concrete with the main focus on the determination of the optimum dosage for improved compressive and flexural strengths of concrete. For compressive strength both destructive and non-destructive tests were carried out while for flexural strength only destructive tests were carried out on the concrete specimens with 0.25%, 0.5% 0.75%, and 1% polypropylene fibers compared to control samples and were tested at different ages of 7, 14, 21 28 days of curing.

The optimum dosage of polypropylene fiber that improved compressive and flexural strengths were found to be in the range of 0.25% and 0.5%. A slight increase in compressive and flexural strength was observed for 0.50% and then a continuous decrease was observed when 0.75% and 1% polypropylene fibers were added. Md Azree Othuman Mydin [14] et al and Roohollah Bagherzadeh [15] et al studied the behavior of lightweight foamed concrete exposed to higher temperatures with PP fibers in the range of 0.1 to 0.5% by volume of concrete and found improvement in mechanical properties. On the basis of the literature survey, 0.5% PP fiber by volume was found to be the optimum dosage of fiber content and the same dosage was used for further study.

3. Experimental Program

For the experimental study, the dosage of PP fibers used was 0.5% of the volume of concrete based on the findings from the literature. In this study, the mix was divided into three concrete batches based on the w/c ratio as 0.2, 0.36, and 0.47. Each concrete batch was exposed to room temperature (27 °C), 400 °C, and 600 °C for 60 minutes. The total number of specimens for each concrete mix were 22 cylinders. 16 concrete cylinders (100 x 200 mm) where 8 cylinders of control mix and 8 of polypropylene mix were cast. An additional 6 cylinders (150 x 300 mm) were cast out of which 3 were of control mix while the other 3 were of polypropylene mix. The heating of the specimen was done in an electrical furnace with a rate of heating as 5 °C/min till the desired temperature is achieved and then exposure temperature was maintained for 1 hour. Cooling to room temperature was carried out in a closed and disconnected furnace (Figure 1).

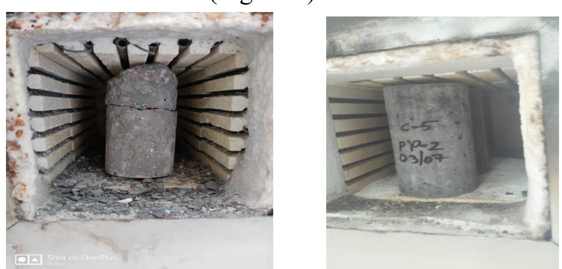

Figure 1. Sample inside the furnace

3.1 Compression Test

The compressive strength test was carried out as per the IS:516. The size of the cylindrical specimen was 100 x 200 mm and for each temperature exposure, 4 cylinders were tested. The cylinders were water-cured at room temperature and were taken out at the age of 28 days. The weight of each specimen was recorded.

3.2 Splitting Tensile Test

A splitting tensile test was carried out as per IS:5816-1999. For each concrete mix at each exposure condition, 2 cylinders were tested with a specimen size of 100x200 mm.

DOI: https://doi.org/10.30564/jaeser.v4i2.3296

4. Effect of Polypropylene Fibers on Mechanical Properties of Concrete

Various researchers have investigated the effect of the addition of fibers on the mechanical properties of concrete explaining it as having a high-performance and more cost-effective concrete composite. This experimental program was carried out to investigate the effect of the addition of polypropylene fiber on the mechanical behavior of concrete at the fiber dosage of 0.5% by volume of concrete. Mechanical properties such as compressive strength, Modulus of Elasticity (MOE), splitting tensile strength, and Poisson's ratio were studied at room temperature with and without polypropylene fibers.

4.1 Compressive Strength

From the compressive test results, it could be clearly found that PP fibers when used as a concrete additive effects the concrete strength. There was a decrease in the value of compression strength of fiber mix when compared to the control mix. Reduction % of compressive strength of fiber mix concrete with respect to plain concrete at room temperature was 2.68% for 0.2 w/c ratio,17.45% for 0.36 w/c ratio and 25.79% for 0.47 w/c ratio (Figure 2). For all w/c ratio value of compressive strength of control mix (CM) was higher than that of polypropylene mix (PP).

Khajuria and Balaguru [5] and Alhozaimy, A.M. [6], carried out a study on polypropylene fiber reinforced concrete and concluded that no significant effect on compressive (or) flexural strength was observed upon addition of fibers, while flexural toughness and impact resistance values were increased. Further, that if more water is added to improve the workability of FRC, a reduction in compressive strength may occur. This reduction in compressive strength should be attributed to additional water or due to an increase in entrapped air and not to the fiber addition in the matrix.

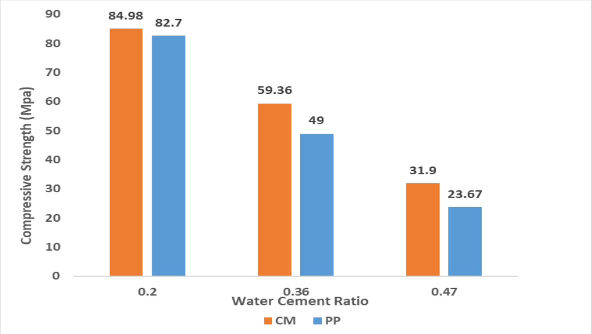

Figure 2. Variation in Compressive Strength

4.2 Modulus of Elasticity

The modulus of elasticity of a material is a measure of its stiffness. MOE values for 0.36 w/c ratio for both mix, CM and PP were very close and no significant improvement was observed. For 0.2 w/c ratio % increase in MOE was 7.4% and for 0.47 w/c ratio % reduction in MOE was 8.3% (Figure 3). No notable improvement was noticed for all w/c cement ratios.

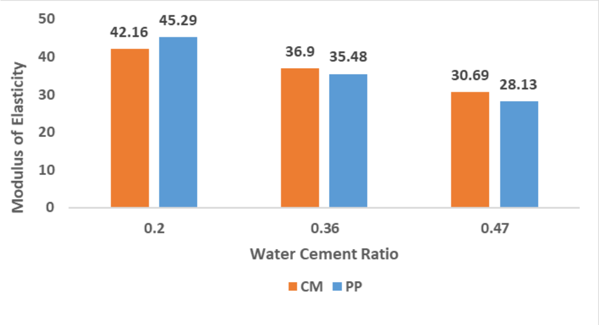

Figure 3. Variation in Modulus of Elasticity

4.3 Poisson Ratio

The Poisson's ratio for the composite is defined as the ratio of transverse strain divided by the longitudinal strain when stress is applied in the longitudinal direction. As from the results obtained, the comparison between the two Poisson's ratios of polypropylene mix and control mix shows that Poisson's ratios are less sensitive to fiber addition. In particular, the values of 0.2 w/c ratio and 0.47 w/c ratio of the control mix are higher than Poisson's ratio of polypropylene mix. On the contrary, values of 0.36 w/c ratio of control mix are marginally lower than that polypropylene mix. As seen from the results in Figure 4, the incorporation of fiber did not give any significant improvement in the values of Poisson's ratio.

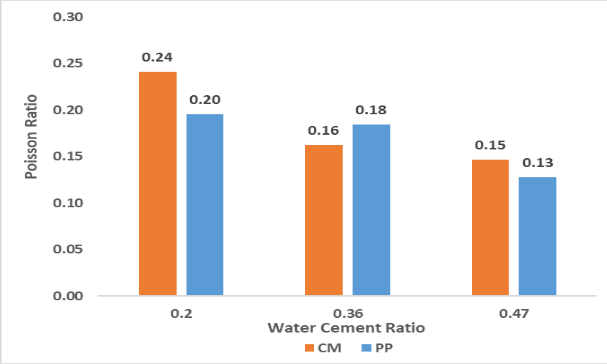

Figure 4. Variation in Poisson's Ratio

4.4 Split Tensile Strength

Due to the brittle nature of the concrete, it is very weak in tension and hence is not expected to resist the direct tension. Concrete develops micro and macro cracks when the tensile stresses in concrete exceed its tensile strength. Therefore, to determine the safe load beyond which the concrete members may crack it becomes necessary to determine the tensile strength of concrete. The incorporation of PP fiber showed no significant effect on split tensile strength. As seen in Figure 5 there is a very marginal difference in values of split tensile strength for polypropylene mix and control mix. Values of split tensile were higher in the control mix than that of polypropylene mix for 0.2 w/c ratio and for 0.36 w/c ratio. A study done by Bentur et al [7] suggests that the addition of polypropylene fibers does not have a significant effect on the direct tensile cracking strength. However, for higher volume replacements in the range of 0.33-0.5%, the addition of macro-synthetic polypropylene fibers resulted in 10-15% increase in splitting tensile strength. But this increment may be the result of the intersample variation. Therefore, it will be good to say that no significant improvement is observed in mechanical properties upon the addition of PP fibers.

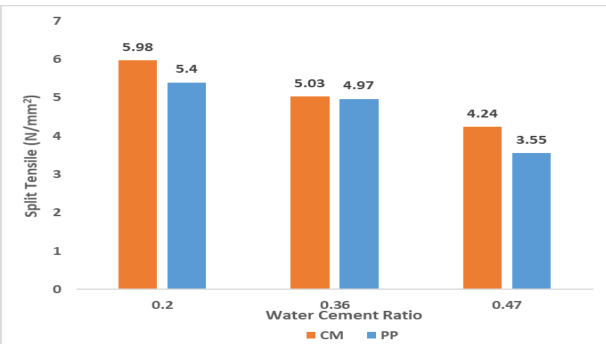

Figure 5. Variation in Split Tensile Strength

5. Mechanical Properties of Polypropylene Fiber Reinforced Concrete Exposed to Elevated Temperature

Synthetic fibers irrespective of their type, shape, and length, are mostly used to increase the spalling resistance of the concrete when exposed to elevated temperatures. The presence of fibers in the concrete composite exposed to elevated temperature affects its mechanical properties due to the generation of voids as the melting point of synthetic fibers is relatively low. In this study effect of PP fiber on compressive strength and split tensile strength when exposed to elevated temperature was explored.

Many studies in the past concluded that polypropylene fibers have a negative effect on the residual mechanical properties of polypropylene fiber reinforced concrete after exposure to higher temperature exposure as they significantly decrease the residual compressive strength, elastic modulus, and tensile strength [16-18]. While some experimental studies show that polypropylene fibers can improve the residual compressive strength of a concrete composite after exposure to elevated temperatures [19]. Some even say that the presence of polypropylene fibers at different dosages does not affect the residual compressive strength at up to 400 °C, but significantly increases the residual compressive strength of concretes after 600 °C [20].

5.1 Compressive Strength for 0.5% Fiber Mix

From the compressive test results, it could be clearly found that PP fibers when used as a concrete additive reduced the compressive strength. Value of % reduction in compressive strength for both mixes at 400 °C & 600 °C did not have much difference (Figure 6 & Figure 7). Hence, there was no significant impact of PP fiber on normal and high-strength concrete at elevated temperatures. This research suggests that the compressive strength of concrete containing PP fibers (0.5%) has no significant impact on plain concrete and no major improvement in strength was observed in fiber reinforced high strength concrete exposed to elevated temperatures.

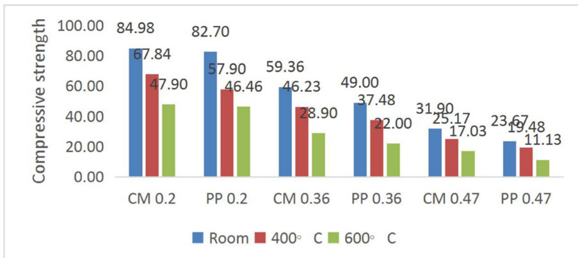

Figure 6. Compressive strength variation at different temperature for different w/c ratio

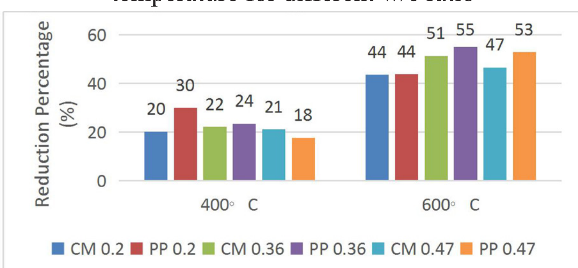

Figure 7. Reduction percentage in compressive strength at different temperature for different w/c ratio

5.2 Split Tensile Strength for 0.5% Fiber Mix

Values of % reduction in split tensile strength at 600 °C were marginally higher for the control mix than that of the fiber mix. No significant improvement in values was noted at 400 °C (Figure 8 & Figure 9). It can be concluded that polypropylene fiber when exposed to 400 °C doesn't have any notable positive impact but at 600 °C very marginal

DOI: https://doi.org/10.30564/jaeser.v4i2.3296

enhancements in tensile properties could be seen.

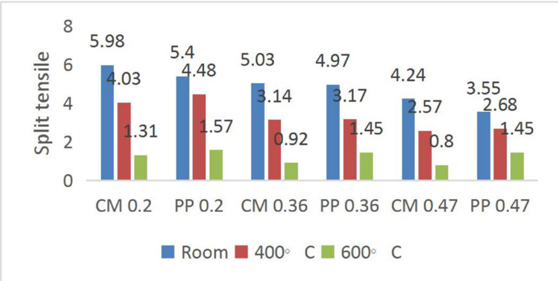

Figure 8. Variation in Split Tensile strength at different temperature for different w/c ratio

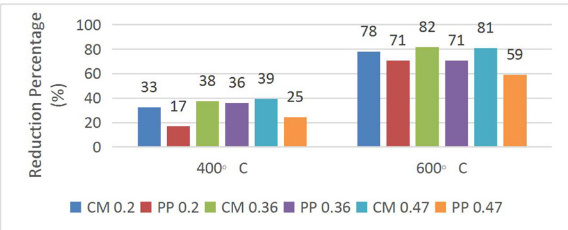

Figure 9. Reduction percentage in Split Tensile strength at different temperature for different w/c ratio

5.3 Flexural Strength for 0.5% Fiber Mix

The ability of concrete to resist in flexure can be defined as the flexural strength of the concrete and is also known as the modulus of rupture. Flexure test was done on 100*100*500 beams, 4 for each temperature. As seen in Figure 12, flexure strength for the control mix (CM) was higher than that of polypropylene mix (PP) for all temperatures. Hence from the experimental study on flexural strength, no improvement due to polypropylene fiber was observed at elevated temperature for 0.20 w/c ratio (Figure 10 & Figure 11).

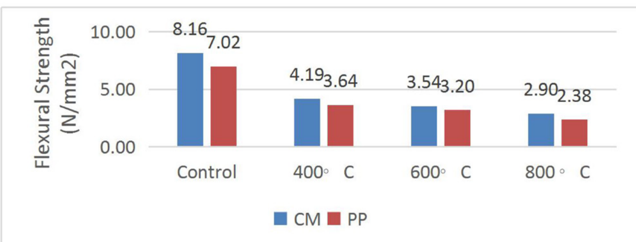

Figure 10. Variation in flexural strength at different temperature for different w/c ratio

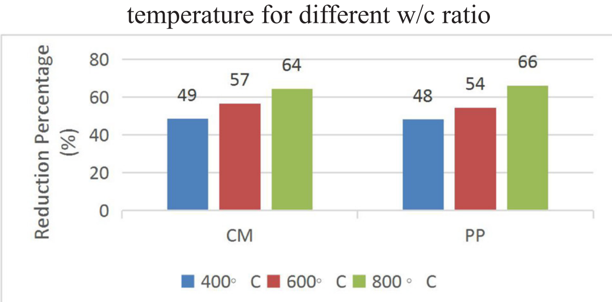

Figure 11. Reduction percentage in flexural strength at different temperature for different w/c ratio

5.4 Spalling Resistance for 0.5% Fiber Mix

Spalling resistance of the concrete can be attributed to the surface texture after exposure to the elevated temperature as compared to the surface texture of the concrete without exposure to fire. As the exposure temperature is increased the spalling in the concrete increases. The concrete samples without fibers when exposed to elevated temperature, most of the cylinders were blasted inside the furnace, or even if not blasted the spalling in excess was observed on the surface. The compressive strength so observed in the controlled sample after exposure to elevated temperature was mainly due to the intact core of the cylinder only i.e., the actual load-bearing cross-sectional area was decreased which may be the reason for the decrease in the compressive strength of the concrete. However, the concrete samples with polypropylene fibers did not blast or the spalling on the surface was observed only in the form of the minor cracks (Figure 12). But no major enhancement in the concrete compressive strength was observed.

(a) Cylinder with control mix after blast in the furnace

(b) Cylinder with control mix with severe spalling

DOI: https://doi.org/10.30564/jaeser.v4i2.3296

(c) NSC Cylinder with PP fiber after exposure during testing

(d) HSC Cylinder with PP fiber after exposure to elevated temperature during testing

Figure 12. Cylinders after exposure to elevated temperature and during testing

6. Results and Discussions

● It is observed that the percentage reduction in compressive strength was highest for polypropylene mix at 600 °C. Values of percentage reduction in compressive strength did not decrease with the incorporation of polypropylene fiber, so it can be concluded that PP fiber has no positive impact in improving the compressive strength of concrete at both room and elevated temperatures.

● Values of split tensile strength were not improved significantly after the incorporation of PP fiber at room temperature. Values of percentage reduction of split tensile strength were similar in both mixes at 0.2 w/c ratio and for 0.36 w/c ratio at 600 °C and for 0.47 w/c ratio values of percentage reduction for control mix was marginally higher than that of polypropylene mix, but no notable improvements could be recorded.

● Similarly, other mechanical properties like MOE and poison's ratio, no trend of positive impact could be established. Values of MOE at the different water-cement ratios for both control and fiber mix were found to be similar. There was no impact of using polypropylene fiber.

● From the experimental investigation, it was observed that when fibers are used in concrete it does not enhance any mechanical properties of concrete at both room and elevated temperatures. This trend was observed with a fiber percentage of 0.5% by volume. Most of the earlier researchers have claimed an increase in the range of 4 to 6 percent in mechanical properties including compressive strength, splitting tensile strength, and flexural strength upon addition of polypropylene fibers. However, this increase may be due to the inter-sample variation of the same concrete batch or due to the variation in the testing of individual samples.

● The spalling resistance of the concrete at elevated temperature was improved by the addition of polypropylene fibers as the samples with fibers were not broken after exposure to high temperatures.

7. Conclusions

In this current study, the impact of the addition of polypropylene fibers on concrete fire resistance at elevated temperatures was studied and no significant enhancement in mechanical properties such as modulus of elasticity, Poisson's ratio, splitting tensile strength, flexural strength, and compressive strength was observed upon addition of polypropylene fibers for High Strength Concrete. Hence, it is concluded that the addition of polypropylene is not sustainable nor economical despite the various claims in past regarding its positive impact on fire resistance of normal strength concrete. However, the spalling resistance of the concrete at elevated temperature was improved by the addition of polypropylene fibers and the addition of an optimum percentage of fiber will be beneficial in the high strength concrete to avoid spalling. Based on the outcome of the study, the recommendations have been given for revision of Indian Standard IS:456-2000 for incorporating polypropylene fibers mainly in high strength concrete to avoid spalling during the event of a fire which can lead to damage in cover concrete and thereby creating durability related issues during the service life of the structure. Further studies can be carried out using different fiber doses which may result in higher residual mechanical properties after exposure to elevated temperatures and can lead to an effective and sustainable solution for fire damages.

References

[1] V.V.Arora, Brijesh Singh and Shubham Jain, "Effect

DOI: https://doi.org/10.30564/jaeser.v4i2.3296

of indigenous aggregate type on mechanical properties of high strength concrete" Indian Concrete Journal, Vol. 91, No. 1, pp. 34-44, January 2017, NCCBM, Haryana, India.

[2] V. V.Arora, Brijesh Singh and Shubham Jain, Indian "Experimental studies on short term mechanical properties of high strength concrete" Concrete Journal, Vol. 90, No. 10, pp. 65-75, October 2016, NCCBM, Haryana, India.

[3] Cetin, A. and Carrasquillo, R. L. 1998. High-Performance Concrete: Influence of Coarse Aggregates on Mechanical Properties, Journal of ACI Materials, 95: 252-261.

[4] Ashour, S. A., "Effect of compressive strength and tensile reinforcement ratio on flexural behavior of high-strength concrete beams," Engineering Structures, Vol.22, 2000, pp. 413-423.

[5] BALAGURU, P., "Properties and Behavior of Fiber Reinforced Concrete," General Report, Technical Sessions 2, Proceedings of International Symposium on Fiber Reinforced Concrete, Volume III, 1987, pp. 2.48-2.52.

[6] Alhozaimy, A.M.; Soroushian, P.; and Mirza, F. (1996). Mechanical properties of polypropylene fiber reinforced concrete and the effect of pozzolanic materials. Cement and Concrete Composites, 18(2), 85-92.

[7] Bentur A. and Mindess S., 1990, Fibre Reinforced Cementitious Composites, Elsevier Science Publishing Ltd., New York, United State of America.

[8] A. Nishida & N. Yamazaki (1995)." Study on the Properties of High Strength Concrete with Short Polypropylene Fibre for Spalling Resistance". Proceedings of the International Conference on Concrete under Severe Conditions (CONSEC'95). Sapporo, Japan. August. E&FN Spon, London, pp: 1141-1150.

[9] P. Kalifa, G, Chene& Ch. Galle (2001)." High-Temperature Behaviour of HPC with Polypropylene Fibres from Spalling to Microstructure".Cement & Concrete Research. 31, pp: 1487-1499.

[10] Optimal Polypropylene Fiber Content for Improved Compressive and Flexural Strength of Concrete Anthony Nkem Ede1 (Ph.D.) and Abimbola Oluwababmi Ige, Department of Civil Engineering, College of Science and Technology, Covenant University, Canaan Land, KM 10, Idiroko Road, P.M.B. 1023 Ota, Ogun State, Nigeria.

[11] Shihada, S., 2011. Effect of Polypropylene Fibers on Concrete Fire Resistance. Journal of Civil Engineering and Management, Accepted for Publication.

[12] Effects of various dosage of PPF on compressive strength of PMM (sbr), PMM (acrylic) and microconcrete Kamlesh S.Dalal., Modhera, C.D, and S.A. Vasanwala Dept. of Applied Mechanics, S V National Institute of Technology, Ichchhanath, Surat-395007, India.

[13] Optimal Polypropylene Fiber Content for Improved Compressive and Flexural Strength of Concrete Anthony Nkem Ede1 (Ph.D.) and AbimbolaOluwabambi Ige1 1Department of Civil Engineering, College of Science and Technology, Covenant University, Canaan Land, KM 10, Idiroko Road, P.M.B. 1023 Ota, Ogun State, Nigeria.

[14] Md Azree Othuman Mydin and Sara Soleimanzadeh, "Effect of polypropylene fiber content on flexural strength of lightweight foamed concrete at ambient and elevated temperatures," Pelagia Research Library, Advances in Applied Science Research, 2012, 3 (5):2837-2846.

[15] Roohollah Bagherzadeh, Ph.D., Hamid Reza Pakravan, Abdol-Hossein Sadeghi, Masoud Latifi, Ali Akbar Merati, "An Investigation on Adding Polypropylene Fibers to Reinforce Lightweight Cement Composites (LWC)," Journal of Engineered Fibers and Fabrics, Volume 7, Issue 4 – 2012.

[16] Sideris K K, Manita P and Chaniotakis E Performance of thermally damaged fibre reinforced concretes 27 September 2009 Construction and Building Materials 23 1232-1239.

[17] Sideris K K and Manita P. Residual mechanical characteristics and spalling resistance of fiber-reinforced self-compacting concretes exposed to elevated temperatures 11 January 2013 Construction and Building Materials 41 296-302.

[18] Khaliq W and Kodur V Thermal and mechanical properties of fiber-reinforced high-performance self-consolidating concrete at elevated temperatures 24 June 2011 Cement and Concrete Research 41 1112-1122.

[19] Xiangjun D, Yining D and Tianfeng W Spalling and Mechanical Properties of Fiber Reinforced High-performance Concrete Subjected to Fire October 2008 Journal of Wuhan University of Technology-Mater. Sci. Ed 743-749.

[20] Qadi A, Al N S and Sleiman M A Effect of fiber content and specimen shape on residual strength of polypropylene fiber self-compacting concrete exposed to elevated temperatures 10 December 2014 Journal of King Saud University – Engineering Sciences 26 33-39.

 DOI: https://doi.org/10.30564/jaeser.v4i2.3296