STUDIES ON IMPACT STRENGTH OF CONCRETE WITH NANO-MATERIALS AT ELEVATED TEMPERATURES

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ABSTRACT

Fire resistance of concrete structure is an important factor to be considered in the design of building. Fire may cause different degree of damage to the structure depending on the temperature and duration of its exposure. Adding of fibers in the concrete improves the residual strength and fracture energy. In this research an experiment investigation has been carried out to determine the influence of concrete with fiber particles under elevated temperature. M40 grade of concrete were cast. In a grade of concrete, 0.25%, 0.5% and 0.75% 1% of cement was replaced with fiber particles. To study the compressive and split tensile strength of fiber reinforced concrete at elevated temperatures (27°C, 100°C, 150°C 200°C and 250°C). Specimens were heated and cooled by the water. Steel fiber, polypropylene fiber, carbon fiber, was added to enhance the fracture energy of concrete at elevated temperature. These specimens were heated by using Muffle furnace. After heating the specimens were allowed to cool by sprayed water in case of water cooling. The mechanical properties Such as compressive and split tensile strength of fiber reinforced concrete specimens were compared with reference specimens (no fiber). The specimens with steel fiber and carbon fiber showed higher strength after exposure to high temperature. And polypropylene could mitigate the spalling of specimens significantly. The use of carbon fiber can be effective in improving the strength and fracture energy of specimens after high temperature.

INTRODUCTION

Concrete is weak in tension and has a brittle character. The concept of using fibers to improve the characteristics of construction materials is very old. Early applications include addition of straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce pottery. Use of continuous reinforcement in concrete (reinforced concrete) increases strength and ductility, but requires careful placement and labour skill. Alternatively, introduction of fibers in discrete form in plain or reinforced concrete may provide a better solution. The modern development of fiber reinforced concrete (FRC) started in the early sixties. Addition of fibers to concrete makes it a homogeneous and isotropic material. When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility. The failure modes of FRC are either bond failure between fiber and matrix or material failure. The addition of fibers significantly improves many of the engineering properties of mortar and concrete, notably impact strength and toughness. Flexural strength, fatigue strength, tensile strength and the ability to resist cracking are also enhanced. Fiber reinforced concrete (FRC) is a composite material consisting of cement, sand, coarse aggregate, water and fibers. In this composite material, short discrete fibers are randomly distributed throughout the concrete mass. The behavioral efficiency of this composite material is far superior to that of plain concrete and many other construction materials of equal cost. Due to this benefit, the use of FRC has steadily increased during the last two decades and its current field of application includes: airport and highway pavements, earthquake-resistant and explosive-resistant structures, mine and tunnel linings, bridge deck overlays, hydraulic structures, rock- slope stabilization, etc.

REVIEW OF LITERATURE

Dr.T.Ch.Madhavi 2014 Concrete has better resistance in compression while steel has more resistance in tension. Conventional concrete has limited ductility, low impact and abrasion resistance and little resistance to cracking. A good concrete must possess high strength and low permeability. Hence, alternative Composite materials are gaining popularity because of ductility and strain hardening. To improve the post cracking behavior, short discontinuous and discrete fibers are added to the plain concrete. Addition of fibers improves the post peak ductility performance, pre-crack tensile strength, fracture strength, toughness, impact resistance, flexural Strength resistance, fatigue performance etc. The ductility of fiber reinforced concrete depends on the ability of the fibers to bridge cracks at high levels of strain. Addition of polypropylene fibers decreases the unit weight of concrete and increases its strength.

Y. Mohammadi (2008) studied the impact resistance of steel fiber reinforced concrete containing fibers of mixed aspect ratio. An experimental investigation was planned in which 108 plain concrete and SFRC beam specimens of size 100x100x500 mm were tested under impact loading. The specimen incorporated three different volume fractions i.e. 1.0%, 1.5% and 2.0% of corrugated steel fibers. Each volume fraction incorporated mixed steel fibers of size 0.6 x 2.0 x 25 mm and 0.6 x 2.0 x 50 mm in different proportions. The drop weight type impact tests were conducted on the test specimens and the number of blows of the hammer required to induce first visible crack and ultimate failure of the specimen were recorded. The results are presented in terms of number of blows required as well as impact energy at first crack and ultimate failure. It has been observed that concrete containing 100% long fibers at 2.0% volume fraction gave the best performance under impact loading.

Jianzhuang Xiaoa (2006) carried out experiment on material properties of concrete with polypropylene fiber under elevated temperature. These specimens were heated in an electric furnace, approximately following the curve of ISO-834, with a series of target temperatures ranging from 20 to 900°C. No explosive spalling was observed during the fire test on HPC specimens with PP fibers, whereas some spalling occurred for HPC specimens without PP fibers. The relationship between the mass loss and the exposure temperature was investigated. In addition, the heated and cooled cubes and prisms were tested under monotonic compressive loading and four-point bending loading, respectively. The degradation of both the residual compressive strength and the residual flexural strength was analyzed. Furthermore, the effects of PP fibers on the residual mechanical strength of HPC specimens at elevated temperatures were also investigated. Finally, a fire-resistance design curve relating the residual compressive strength to temperature, as well as a design curve relating the residual flexural strength to temperature, was proposed based on the statistical analysis of the test data.

Y.F. Chang (2006) performed experiments on the complete compressive stress–strain relationship for concrete after heating to temperatures of 100– 800°C. All concrete specimens are ϕ15 cm×30 cm standard cylinders, made with siliceous aggregate. The heated specimens are tested at 1 month after they are cooled to room temperature. From the results of 108 specimens with two original unheated strengths, a single equation for the complete stress – strain curves of heated concrete is developed to consider the shape varying with temperature. Through the regression analysis, the relationships of the mechanical properties with temperature are proposed to fit the test results, including the residual compressive strength, peak strain and elastic modulus. Compared with the experimental curves, the proposed equation is shown to be applicable to unheated and heated concrete for different temperatures. In addition, the split-cylinder tests of 54 specimens are also carried out to study the relationship of splitting tensile strength with temperature.

Gai-Fei Peng (2005) carried out experimental investigation to explore the relationship between explosive spalling occurrence and residual mechanical properties of fiber-toughened high-performance concrete exposed to high temperatures. The residual mechanical properties measured include compressive strength, tensile splitting strength, and fracture energy. A series of concretes were prepared using OPC (ordinary Portland cement) and crushed limestone. Steel fiber, polypropylene fiber, and hybrid fiber (polypropylene fiber and steel fiber) were added to enhance fracture energy of the concretes. After exposure to high temperatures ranged from 200 to 800°C, the residual mechanical properties of fiber toughened high-performance concrete were investigated. For fiber concrete, although 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 resistance of concrete to explosive spalling.

Pierre kalifa 2001 The addition of polypropylene (PP) fibers to high-performance concrete (HPC) is one way to avoid spalling of concrete under fire conditions. The present work contributes both to the understanding of the way in which fibers act and to optimizing the fiber dosage. Pore pressure measurements performed on heated specimens showed that the presence of fibers led to a large decrease in the extent of the pressure fields that build up in the porous network during heating. This effect was also significant at dosages lower than the theoretical percolation threshold. These results are supported by permeability measurements carried out after various heat treatments and for various fiber dosages: they showed the striking effect of fibers from 200°C up, that is, very close to their melting temperature. The role of fibers is discussed through the analysis of concrete microstructure and fiber–matrix interactions as function of heat treatment.

K.C.G. Ong (1999) carried out an investigation on fiber concrete slabs subjected to low velocity projectile impact was carried out to assess impact resistance. The main variables of the study were type of fiber and volume fraction of fibers. The types of fibers chosen were polyolefin, polyvinyl alcohol and steel. The volume fraction of fibers examined were 0%, 1% and 2%. A total of 10 square slabs of size 1 m and 50 mm thickness were cast and tested. Impact was achieved by dropping projectile of mass 43 kg from a height of 4 m, by means of an instrumented impact test facility. Test results indicate that hooked-end steel fiber concrete slabs have better cracking and energy absorption characteristics than slabs reinforced with other fibre types. Slabs reinforced with polyvinyl alcohol fibers exhibited higher fracture energy values compared to slabs reinforced with polyolefin fibers.

Nianzhi Wang (1996) carried out experiments on small concrete beams reinforced with different volumes of both polypropylene and steel fibers. The drop height of the instrumented drop weight impact machine was so chosen that some specimens failed completely under a single drop of the hammer, while others required two blows to bring about complete failure. It was found that, at volume fractions less than 0.5%, polypropylene fibers gave only a modest increase in fracture energy. Steel fibers could bring about much greater increases in fracture energy, with a transition in failure modes occurring between steel fiber volumes of 0.5% and 0.75%. Below 0.5%, fiber breaking was the primary failure mechanism and the increase in fracture energy was also modest; above 0.75% fiber pull-out was the primary mechanism with a large increase in fracture energy.

Ezeldin and Balaguru (1989) reported the experimental results on the bond behavior of normal and high-strength concretes made with and without fibers. The bond tests were conducted using a modified pullout test in which the concrete surrounding the bar was in uniform tension. Addition of silica fume results in higher bond strength but causes brittle bond failure. The slip (relative movement between the bar and the concrete) at maximum bond load increases with increase in fiber content.

Romualdi and Batson (1963) published their classical paper on 'Mechanics of crack arrest in concrete'. They concluded that application of linear elastic fracture mechanics to reinforced concrete indicates that the relatively low tensile strength of concrete is not inherent to the material and can be avoided with suitable reinforcement arrangement. At appropriate spacing's, Incipient flaws are prevented from enlarging and propagating throughout the tensile zone. In their research (1963) it was concluded 16 that the first crack strength of concrete improves by mixing closely spaced continuous steel fibers in it. It was established that the increase in strength of concrete is inversely proportional to the square root of the wire spacing. Romualdi et al (1964) demonstrated that continuous steel wires could be replaced by randomly oriented small pieces of steel wires uniformly dispersed in the concrete matrix.2.1

MATERIALS USED

Cement : OPC 53 grade
Fine aggregate: locally available river sand zone 2 having a specific gravity of 2.70
Coarse aggregate: crushed granite coarse aggregate of maximum size 20 mm and having a specific gravity 2.70
Water: water available in the college campus
Steel fiber
Polypropylene fiber
Carbon fiber

Table 1 Detail of Fiber

Different types of fibers	Length (mm)	Elastic modulus (GPa)	Melting point (°C)	Tensile strength (MPa)	Density (g/cm³)
Steel fiber	30	210	1425-1710	90-1250	0.9-1.6
Polypropylene fiber	12	38	234-288	270-650	0.91
Glass fiber	10	69	849-930	550-930	2.46
Basalt fiber	12	100-	650	480-630	2.65
Carbon fiber	12	297	1000	330-750	1.80

ROLE OF FIBERS

Cracks play an important role as they change concrete structures into permeable elements and consequently with a high risk of corrosion. Cracks not only reduce the quality of concrete and make it aesthetically unacceptable but also make structures out of service. If these cracks do not exceed a certain width, they are neither harmful to a structure nor to its serviceability. Therefore, it is important to reduce the crack width and this can be achieved by adding polypropylene fibers to concrete .the bridging of the cracks by the addition of PP fibers. Thus addition of fibers in cement concrete matrix bridges these cracks and restrains them from further opening. In order to achieve more deflection in the beam, additional forces and energies are required to pull out or fracture the fibers. This process, apart from preserving the integrity of concrete, improves the load-carrying capacity of structural member beyond cracking. This improvement creates a long post-peak descending portion in the load deflection curve. Reinforcing steel bars in concrete have the same beneficial effect because they act as long continuous fibres. Short discontinuous fibers have the advantage, however, of being uniformly mixed and dispersed throughout the concrete.

EXPERIMENTAL PROGRAM

In this experimental work, concrete specimens were cast with different fibers. The specimens were cast in this study consist of split tensile cylinders of size 150 * 300*, compressive strength cubes of size150*150*150mm.

Mixture Compositions and Placing

Mixing of FRC can be accomplished by many methods. The mix should have a uniform dispersion of the fibers in order to prevent segregation or balling of the fibers during mixing. Most balling occurs during the fiber addition process. Increase of aspect ratio, volume percentage of fiber, and size and quantity of coarse aggregate will intensify the balling tendencies and decrease the workability. Cement and aggregates are mixed thoroughly by hand and then fibers are added manually. The total fiber volume fraction used for casting is 0.25%, 0.5%, 1%, & 2%. Compared to conventional concrete, fiber reinforced concrete mixes are generally characterized by higher cement factor, higher fine aggregate content, and smaller size coarse aggregate. A

Types of fibers	Average Compressive strength at 28 days (N/mm^2)				
Percentage of fibers	0%	0.25 %	0.5 %	0.75 %	1%
Steel	41.42	46.19	49.38	50.49	44.87
Polypropylene	41.42	45.03	48.12	47.32	41.65
Carbon	41.42	45.92	49.49	48.47	43.89

fiber mix generally requires more vibration to consolidate the mix. External vibration is preferable to prevent fiber segregation. Metal trowels, tube floats, and rotating power floats can be used to finish the surface.

TESTING OF SPECIMENS UNDER ELEVATED TEMPERATURE

An electric furnace was used to heat the specimens. The inner dimensions of the furnace are 500mmx500mmx500mm. The sides and top are lined with electrical heating coils embedded in refractory bricks. The control panel has a temperature controller to prevent damage to the furnace by tripping off, if the temperature inside the furnace exceeds the specified temperature. The maximum operating temperature of the furnace is 750°C. The concrete specimens were exposed to fire inside the furnace and the furnace was heated from 27°C to 250°C. After exposing the specimens to desired temperature and duration, the furnace was switched off and the specimens were taken out of the furnace. The specimens were naturally allowed to reach the room temperature by air cooling and water cooling. Ultimate loads of the specimens were found at 28th day for the reference and other specimens that were subjected to elevated to temperature.

After 28 days of curing the specimens taken out from the curing tank and kept out for one day to avoid moisture. Then the specimens were placed in the furnace. The specimens were heated up to a temperature of 250°C. The specimens were naturally allowed to reach the room temperature by air cooling and water cooling.

Table 2 compressive strength for Different Types of Fibers at 27°C

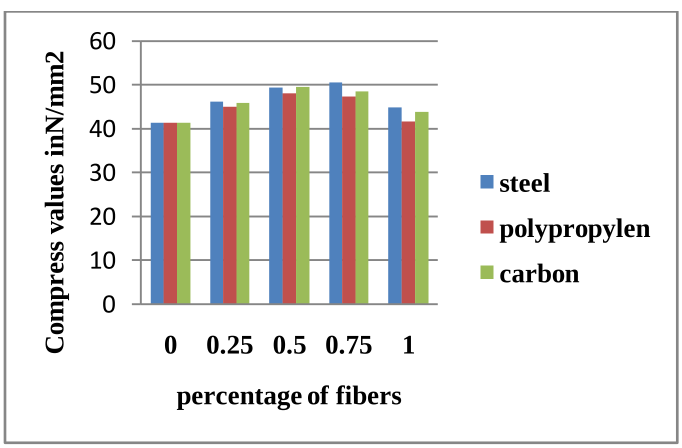

Fig 1 compress strength for Different Types of Fiber at 27°C

Table 3 compressive strength for Different Types of cubes with 0.25% Fibers

	Average Compressive strength at 28 days (N/mm^2)		
Temperature	Steel	Polypropylene	Carbon
27°C	46.19	45.03	45.92
100°C	43.37	42.07	42.95
150°C	42.89	41.98	41.601
200°C	39.23	38.53	39.43
250°C	38.87	36.97	37.48

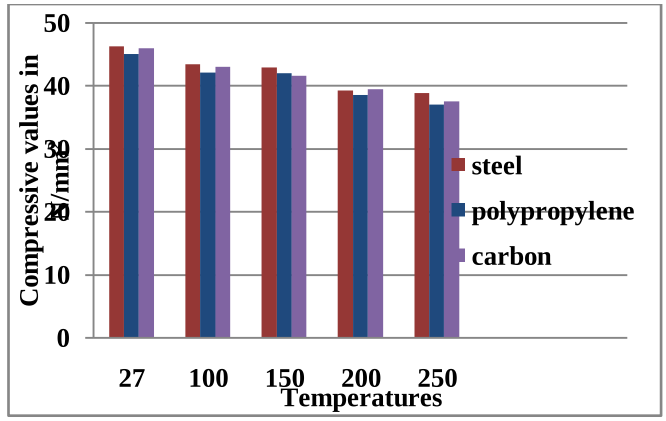

Fig 2 compressive strength for Different Types of cubes with 0.25% Fibers

Table 4: Compressive strength for Different Types of cubes with 0.5% Fibers

Temperature	Average Compressive strength at 28 days		
	Steel	Polypropylene	Carbon
27°C	49.38	48.12	49.49
100°C	45.49	44.93	45.89
150°C	44.97	43.50	43.83
200°C	41.07	39.85	40.63
250°C	39.13	35.47	38.13

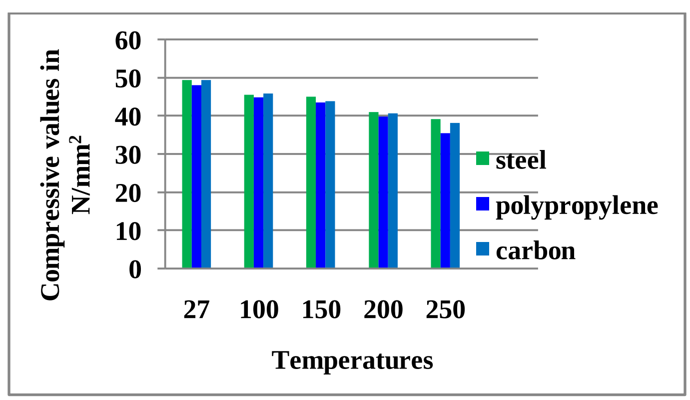

Fig 3: compressive strength for Different Types of cubes with 0.5% Fibers

Table 5: compressive strength for Different Types of cubes with 0.75% Fibers

Temperature	**Average Compressive strength at 28 days**		
	Steel	**Polypropylene**	**Carbon**
27°C	50.49	47.32	48.47
100°C	43.63	41.87	44.60
150°C	40.10	40.69	41.01
200°C	38.14	35.13	37.27
250°C	36.83	31.47	36.09

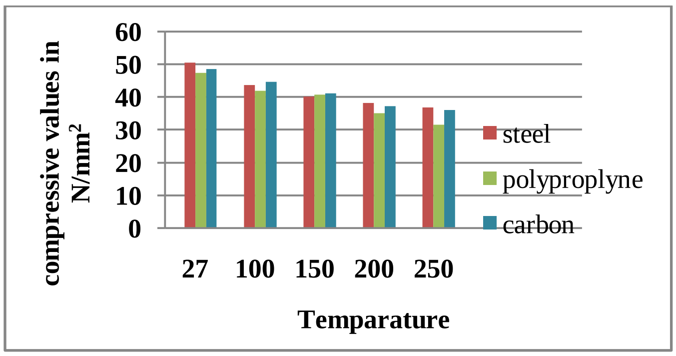

Fig 4: compressive strength for Different Types of cubes with 0.75% Fibers

Table 6: compressive strength for Different Types of cubes with 1.0% Fibers

Temperature	**Characteristic Compressive strength (N/mm^2)**		
	Steel	**Polypropylene**	**Carbon**
27°C	44.87	41.65	43.89
100°C	41.39	39.81	41.07
150°C	39.98	37.34	38.81
200°C	37.35	33.37	36.79
250°C	34.57	29.73	33.83

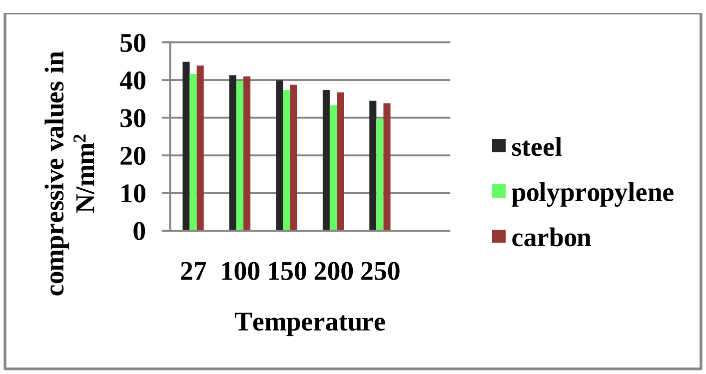

Fig 5: compressive strength for Different Types of cubes with 0.75% Fibers

Table 7: split tensile strength for Different Types of Fibers at 27°C

Types of fibers	**Average tensile strength at 28 days (N/mm^2)(2p/πld)**				
% of	**0**	**0.25**	**0.**	**0.75**	**1**
Steel	4.1	4.49	5.	4.89	4.76
Polyprop	4.1	4.39	4.	4.62	4.49
Carbon	4.1	4.39	4.	4.63	4.57

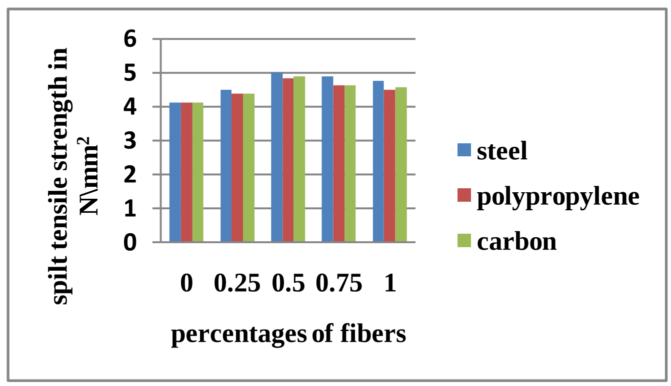

Fig 6: split tensile strength for Different Types of Fibers at 27°C

Table 8: split tensile strength for Different Types of cyinders with 0.25% Fibers

Temperature	**Average tensile strength at 28 days (N/mm^2)**		
	Steel	Polypropylene	Carbon
27°C	4.49	4.39	4.39
100°C	4.18	4.01	4.12
150°C	3.87	3.53	3.73
200°C	3.53	3.29	3.48
250°C	3.12	2.98	3.09

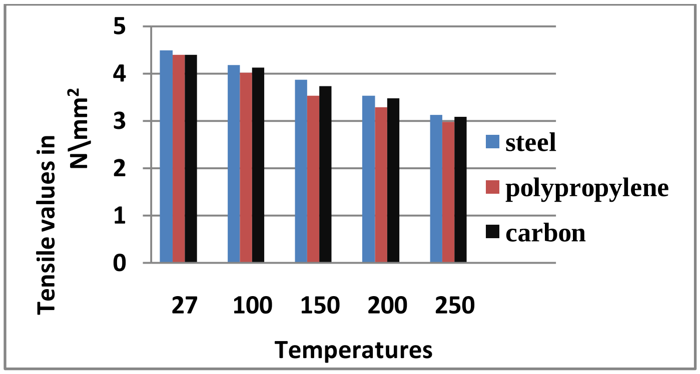

Fig 7: split tensile strength for Different Types of cubes with 0.25% Fibers

Table 9: split tensile strength for Different Types of cubes with 0.5% Fibers

Temperature	**Average tensile strength at 28 days (N/mm^2)**		
	Steel	Polypropylene	Carbon
27°C	5.09	4.83	4.89
100°C	4.73	4.59	4.67
150°C	4.29	4.17	4.23
200°C	4.09	3.85	4.07
250°C	3.78	3.16	3.61

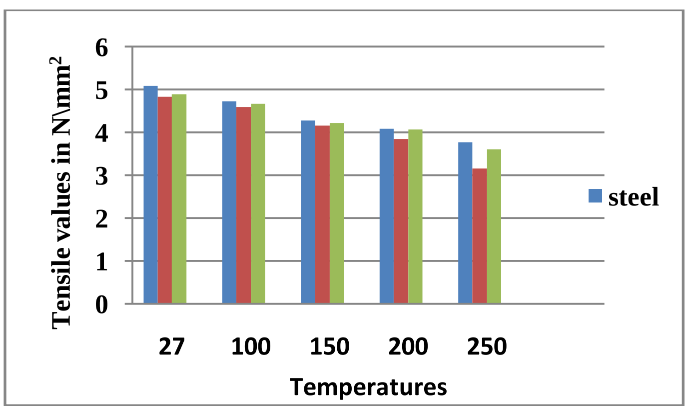

Fig 8: split tensile strength for Different Types of cubes with 0.5% Fibers

Table 10: split tensile strength for Different Types of cubes with 0.75% Fibers

Temperature	**Average tensile strength at 28 days (N/mm^2)**		
	Steel	Polypropylene	Carbon
27°C	4.89	4.62	4.63
100°C	4.59	4.37	4.58
150°C	4.23	3.91	4.17
200°C	3.96	3.62	3.82
250°C	3.65	3.01	3.69

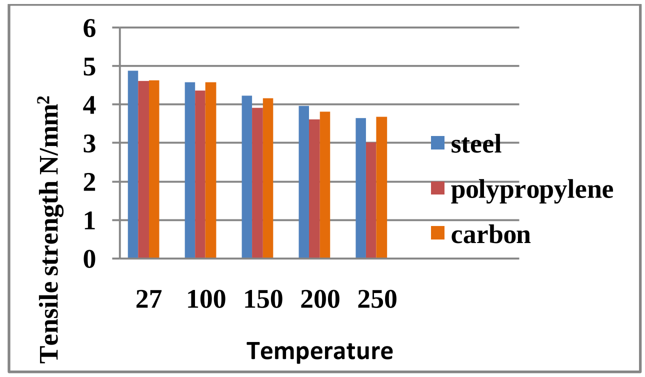

Fig 9: split tensile strength for Different Types of cubes with 0.75% Fibers

Table 11: split tensile strength for Different Types of cubes with 1.0% Fibers

Temperature	**Average tensile strength at 28 days (N/mm^2)**		
	Steel	Polypropylene	Carbon
27°C	4.76	4.49	4.57
100°C	4.43	4.13	4.23
150°C	4.08	3.84	3.98
200°C	3.78	3.41	3.53
250°C	3.39	2.97	3.19

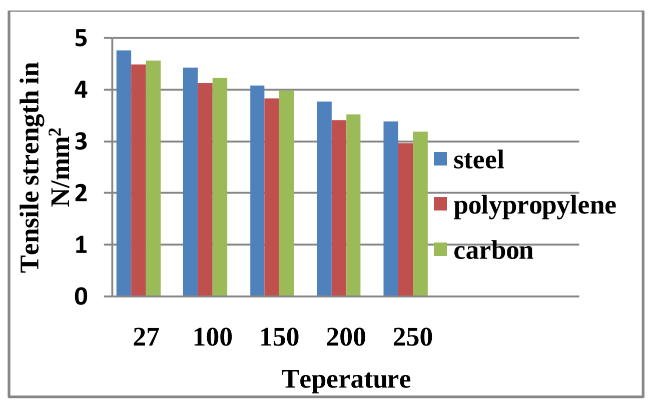

Fig 10: split tensile strength for Different Types of cubes with 1.0% Fibers

CONCLUSION

Based on the experimental investigation the compressive, tensile strength of heated specimens at 27°C increases in case of water cooling about 51%, 48% ,43%, 45%, and 38%, respectively for the specimens with steel fiber, carbon fiber. It decreases about 31% and 33% for the specimens with polypropylene fiber compared to reference specimens (without fiber) in the `case of water cooling respectively.

The compressive, tensile strength of heated specimens at 100°C increases in case of water cooling about 38%, 35%, 27%, and 40%, 35%, 32% respectively for the specimens with steel fiber, carbon fiber. It decreases about 2 8% and 21% for the specimens with polypropylene fiber compared to reference specimens (without fiber) in the case of air and water cooling respectively.

The compressive, tensile strength of heated specimens at 150°C increases in case of water cooling about 47%, 38%, 26% and 38%, 28%, 22%, respectively for the specimens with steel fiber, carbon fiber. It decreases about 25% and 26% for the specimens with polypropylene fiber compared to reference specimens (without fiber) in the case of water cooling respectively.

When the percentage of fiber increases, the compressive, tensile strength of the concrete also increases in water cooling when compared to the normal specimens.

The compressive strength of heated specimens in case of 200°C increases the strength of specimens will decreases in percentages respectively 22%, 28%, 21%, and 19% for the specimens with steel fiber, carbon fiber, and polypropylene fiber respectively compared to reference specimens (no fiber).

The cubes of compressive strength of heated specimens in case of water cooling increase about 52%, 45% and 32% for the specimens with steel fiber, carbon fiber compared to reference specimens (no fiber).

It suggested that use of steel fiber, carbon fiber in concrete can be very effective in reducing the thermal stress and improving composite effects on post cracking behavior during heating process at high temperature.

During the high temperature polypropylene fiber can mitigate or prevent the explosive spalling, but does not increase the fracture energy of the specimens.

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