COMPRESSIVE BEHAVIOUR OF STEEL AND PP FIBERS IN HPC SUBJECTED TO HIGH TEMPERATURE

Gauri kadam[1], V.S.Shingade[2]

[1] *Student, M.E.-II,Civil Engg. Dept.Trinity College of Engineering & Research, Pune Maharashtra,India*
[2] *Faculty, Civil Engg. Dept.Trinity College of Engineering & Research, Pune Maharashtra,India*

ABSTRACT

In this paper, the effects high temperatures on the compressive strength of concretes are presented. High performance concrete was prepared in two series, using plain ordinary Portland cement (PC), and steel & pp fiber. The different percentages of fibers are considered depending on that three series of mixes were prepared. Each series comprised a concrete mix, prepared without any fibers, and concrete mixes reinforced with either or both steel fibers and polypropylene fibers.

Key words: *steel fibers; PP fibers; compressive behavior*

1. INTRODUCTION

Concrete made with Portland cement has certain characteristics. It is relatively strong in compression but weak in tension and tends to be brittle. These two weaknesses have limited its use. Another fundamental weakness of concrete is that cracks start to form as soon as concrete is placed and before it has properly hardened. These cracks are major cause of weakness in concrete particularly in large onsite applications leading to subsequent fracture and failure and general lack of durability. The weakness in tension can be overcome by the use of conventional rod reinforcement and to some extent by the inclusion of a sufficient volume of certain fibers.

Latest developments in concrete technology now include reinforcement in the form of fibers, notably polymeric fibers as well as steel or glass fibers. Fiber-reinforcement is predominantly used for crack control and not structural strengthening. Although the concept of reinforcing brittle materials with fibers is quite old; the recent interest in reinforcing cement based materials with randomly distributed fibers is based on research starting in the 1960's. Since then, there have been substantial research and development activities throughout the world. It has been established that the addition of randomly distributed polypropylene fibers reduced the plastic cracking and steel fibers increase their fracture toughness, ductility and impact resistance. Since fibers can be premixed in a conventional manner, the concept of polypropylene fiber concrete has added an extra dimension to concrete construction. There is a hardly anyone type of fiber that can improve all the desired properties of fresh and hardened concrete. To improve all properties of concrete the combination of two or more types of fibers is required and the composite is known as “hybrid fiber reinforced concrete”. The basic purpose of using hybrid fibers is to control cracks at different size levels in different zones of concrete, stress levels and to enhance the properties of concrete by combining the benefits that each particular fiber type can impart.

The infrastructure development is an important aspect for the overall development of country. India is developing as a major hub for service industry, automobile industry and for which the infrastructure development plays an important role. In case of infrastructure development construction of bridges, aqueducts, high rise buildings, off shore structures, nuclear power stations, dams, high strength concrete above M55 is commonly adopted. The necessity of high strength concrete is increasing because of demands in the construction industry.

High performance concrete is a complex system of materials that perform most effectively when placed in severely aggressive environments. It has found widespread usage in construction application including bridges, tunnels and high-rise building. Concrete in normal conditions is a versatile, resistant, and durable construction material. However under several physical and chemical processes as well as certain environmental conditions, it may deteriorate in a short period of time. As the use of high-performance concrete becomes common, the risk of exposing it to elevated temperatures also increases. The behavior of high performance concrete under elevated temperatures differs from that of plain concrete.

2. LITERATURE REVIEW

Experiment Effect of high temperatures on high performance steel fibre reinforced concrete

In this paper study of the compressive strength, flexural strength, elastic modulus and porosity of concrete reinforced with 1% steel fibre (SFRC) was done when subjected to different elevated heating temperatures, ranging between 105 °C and 1200 °C and changes of colour to the heated concrete have been investigated.

The results show a loss of concrete strength with increased maximum heating temperature and with increased initial saturation percentage before firing. For maximum exposure temperatures below 400 °C, the loss in compressive strength was relatively small. Significant further reductions in compressive strength are observed, as maximum temperature increases, for all concretes heated to temperatures exceeding 400 °C. High performance concretes (HPC) start to suffer a greater compressive strength loss than normal strength concrete (NSC) at maximum exposure Temperature of 600°C. It is suggested that HPC suffers both chemical decomposition and pore-structure coarsening of the hardened cement paste When C–S–H starts to decompose at this high temperature.

Study on Hybrid length Steel Fiber Reinforced Concrete Subjected to Elevated Temperatures

In this paper they have studied the effect of steel fibers on compressive strength of concrete at different temperatures. & they also minimized experimental procedure according to Box-Behnken design for optimization. The conclusions obtained from the test results are the compressive strength and split tensile strength increases with the increase in the % of steel fibers. As temperature increases the strength decreases in the case of 0% steel fiber mixes. It is found that increase in temperature the compressive strength reduction is very small in steel fiber containing specimen. As in case of 1% steel fiber the tensile strength is very much higher compared to the control mix specimen. Reduction in compressive strength appears to be decrease in a systematic manner with increase in steel fibers.

Enhancement of Concrete Sustainability under Temperature Variation using Hybrid Fibre Reinforcement

This study focuses on the performance enhancement of concrete structures under adverse conditions using hybrid fibre reinforcement. A carefully designed slag based concrete mix was arrived based on the three phase particle interaction with a significant reduction in the total cement content. Longer and shorter combination of steel (60mm and 35mm) and polypropylene (47mm and 23.5mm) fibres were used in this study subjected to temperature variation (200°C, 400°C, 600° C and 800°C). Many studies proved the performance of fibre under temperature variation but this study elaborates the significance of the type and size of fibres contributes to the sustainability of the concrete under adverse condition. The comparative assessment is made to understand the performance of each fibre combination under temperature effects. Test results show each hybrid combination shows better results than plain concrete and it purely depends on the fibre used. Even though the role of fibre is less in case of compressive strength but the effect of temperature on the type of fibre is clearly showcased elaborately in this paper.

Compressive strength of polypropylene fiber concrete under the effects of high temperatures

The main purpose of this study is to investigate the effects of high temperature on the compressive strength of concrete. Therefore, the experiments were carried out by mixing woolen type of polypropylene fiber into the concrete. Woolen polypropylene fiber affects the workability of the fresh concrete adversely and it decreases the slump result almost 31% in comparison with control specimens. In the compressive strength test, the maximum strength has been obtained for the concrete by mixing 600 g/m3 woolen polypropylene fiber at 300°C. The strength increasing is about 10.1% in comparing with the control specimens and the minimum strength has been obtained for the concrete by mixing in 900 g/m3 woolen polypropylene fiber at 750°C. Therefore polypropylene fiber has less influence on the compressive strength of concrete

Coupled effect of high temperature and heating time on the residual strength of normal and high-strength concretes

This paper is part of a present research that leads to estimate the level of concrete degradation properties altered by high temperatures, especially by using the maturity concept. In order to evaluate the coupled effect of high temperature and heating time on the residual strength of concrete, a series of compressive and indirect tensile tests was performed on normal and high strength concretes. The effect of incorporating polypropylene fibers in high strength concretes was also investigated. Cubical concrete specimens were exposed to different target high temperatures (100, 300, 500 and 700 ºC) for 3, 6 and 9 hours and then cooled in air. Compressive and flexural strengths of these concrete samples were compared with each other and with the unheated samples. Experimental results indicate that concrete strength decreases with increasing temperature and heating time. The grade of concrete affects the residual compressive and flexural strength; the decrease in the strength of ordinary concrete is more than that in High Performance Concrete (HPC), the effect being more pronounced as the heating time increases. Polypropylene fibers were found to have a beneficial effect on residual strength of HPC at least at high temperatures over their melting and vaporization.

3. EXPERIMENTAL DETAILS

A. Material:

1) Cement – ordinary Portland cement 53. The type / brand of cement is chettinade 53 grade. The specific gravity of cement is 3.15.

2) Coarse and fine aggregate-

The 20 mm aggregate is used having specific gravity 2.920g/cm^3.

3) Fibers: - the steel fibers used were hooked fibers with a length of 25mm and aspect ratio of 60. The polypropylene fibers are used manufactured by propex concrete systems U.S.A. in an ISO 9001:2008 certified manufacturing facility certified by BBA.

Fig. 1 pp fiber

Fig. 2 steel fiber

4) Water: - potable tap water available in the site was used in the present investigation for both casting and curing.

B. Mix proportioning

A. design stipulations

1) Characteristic compressive strength at 28 days = 55 N/mm^2.

2) Maximum size of aggregate = 20mm

3) Workability (slump) = 120 to 130 mm

4) Type of exposure – mild

B. Test data for concrete ingredients.

1) Type/ brand of cement – chettinade 53 grade

2) Specific gravity of cement -3.15

3) Specific gravity of coarse & fine aggregate

20 mm – 2.920, c/sand- 3.83

C. target mean strength

(Assumed standard deviation 5N/mm^2 as per IS456:2000)

Target mean strength = fck + (1.65×S.D)= 63.25 N/mm^2.

D. quantities of ingredients (by absolute volume method)

Cement used – 500kg/m^3

W/c – 0.29

Absolute volume of cement-0.159m^3

Absolute volume of free water – 0.145m^3

Volume of air- 0.020 m^3

Total absolute volume of aggregates = 1-(0.159+0.02+0.145) =0.676m^3.

E. total quantity of coarse and fine aggregate=1926 kg/m^3

F. quantity of ingredients required for 1m^3 of

Concrete -500 kg/m^3

20 mm aggregate- 1105kg/ m^3

C/sand – 821 kg/m^3

Water 145Ltr/m^3

Admixture – vardhman -5kg/m^3

C. series of mixes-

A total of 12 concrete mixes were prepared in each series with different cementitious materials constitutions. While Series I mixes were prepared with plain ordinary PC, and without fibers. Series II mixes were prepared with 1.1% of steel fiber, and Series III mixes were prepared with 0.22% pp fiber. Series IV mixes were prepared with 1.1% steel +0.22pp fiber. And same 4 series were prepared by using Ground granulated blast furnace slag.

Table: - percentage of fibers

mix	Addition of fibers
PC0	No
PC1	1% steel
PC2	0.22% PP
PC3	1%steel + 0.22% PP

d. Methodology

They arrived mix proportions were thoroughly mixed with corresponding percentage of fibers and cube specimen of size 150×150×150mm were casted and cured for 28 days under normal condition. After that three specimens were tested. Remaining 6 specimens were subjected to 600̊c and 800 ̊c. The compressive strength of the concrete specimens was tested and results were analyzed as per Is516-1959.

Heating regime

The kiln used to heat the cylinders was a locally manufactured kiln with a maximum Temperature rating of 600°C. It was a small capacity kiln capable of fitting a maximum of six Cubes at any one time. To monitor the temperatures, four 'type *K*' thermocouples were set up in different positions inside the kiln and in the cube. Two thermocouples were set up to monitor the air temperature inside the kiln. One was positioned 50mm from the top of the interior, and another was set 50mm from the bottom of the kiln. The other two thermocouples were inserted in to a sacrificial cylinder to monitor the core temperature of the sample. All four thermocouples were then connected to a data logger to monitor the temperatures inside the kiln and cylinder. Irrespective of the target temperature, the testing method remained the same throughout. This heating rate was continued until the ambient temperatures inside the kiln reached the target temperature. At this point, the target temperature was maintained, and the concrete was held in the kiln for a further 2 hours.

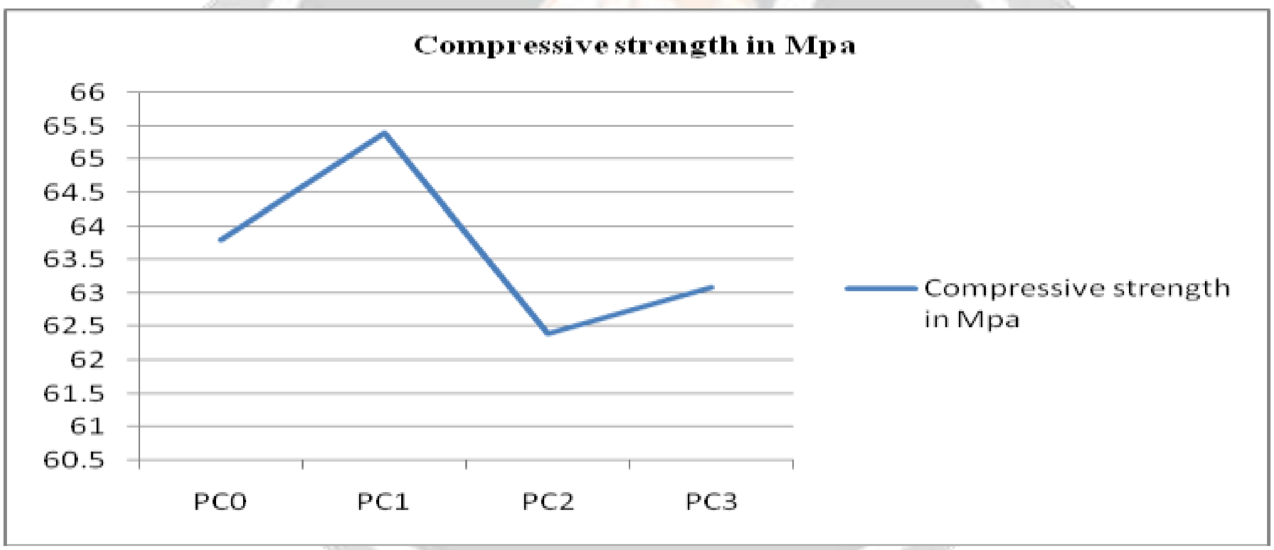
Fig 3 casting of cube specimen

Fig 4 casting of cube specimen

4. RESULTS:

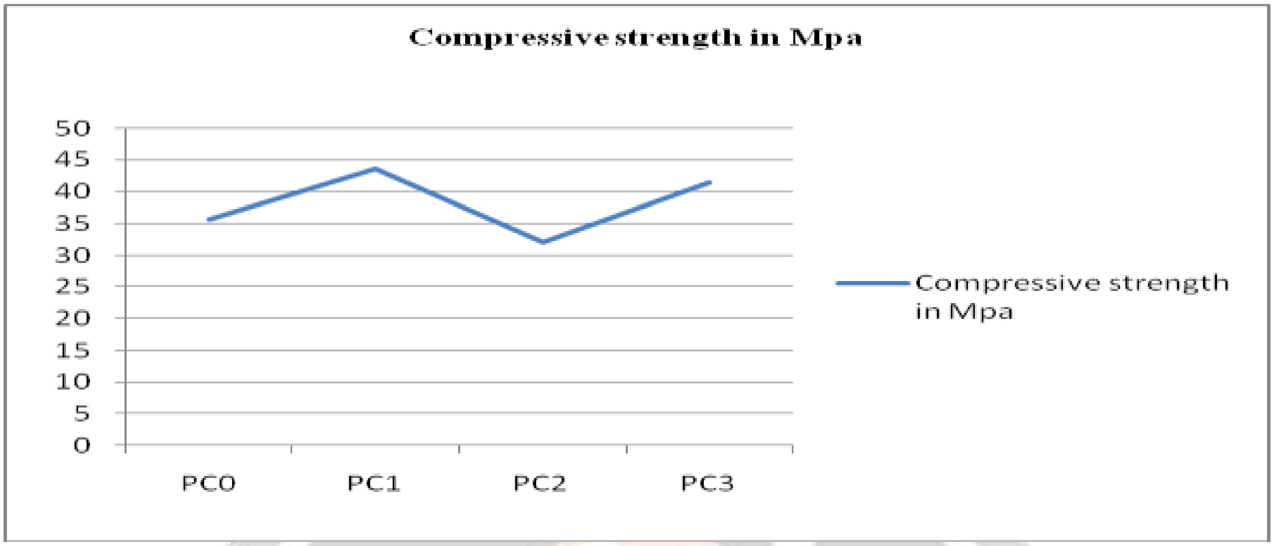
1 Test results for cube of unheated concrete

mix	Addition of fiber	Compressive strength in Mpa
PC0	No	63.8
PC1	1% steel	65.4
PC2	0.22% PP	62.4
PC3	1%steel + 0.22% PP	63.1



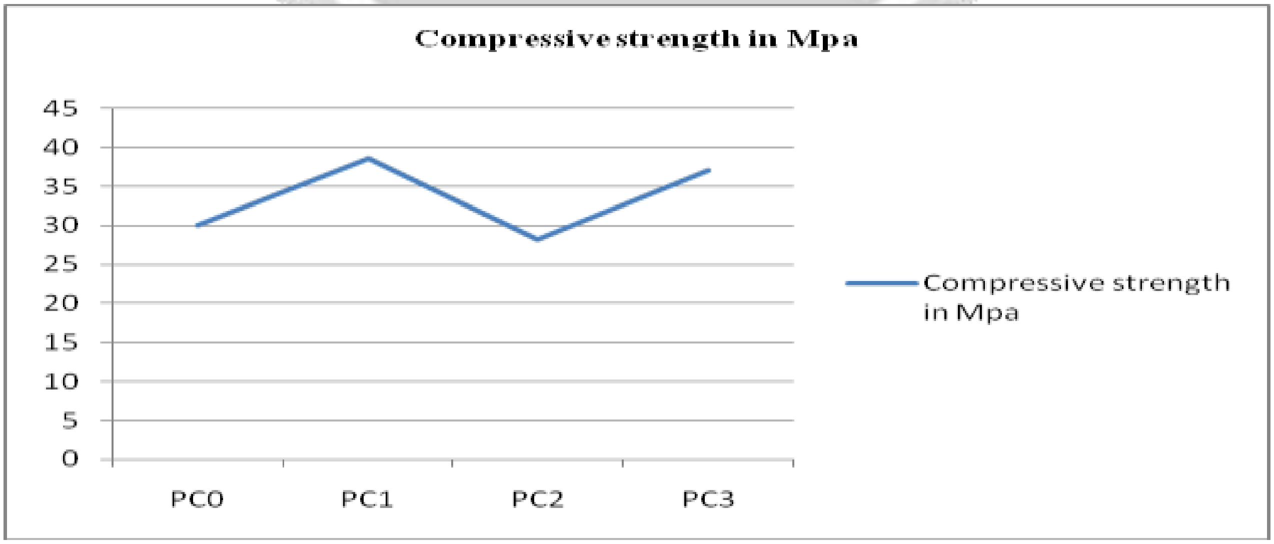
2 Test results of concrete after exposure to 200^{0}C

Mix	Addition of fibre	Compressive strength in Mpa
PC0	No	35.79
PC1	1% steel	43.63
PC2	0.22% PP	32.1
PC3	1%steel + 0.22% PP	41.5



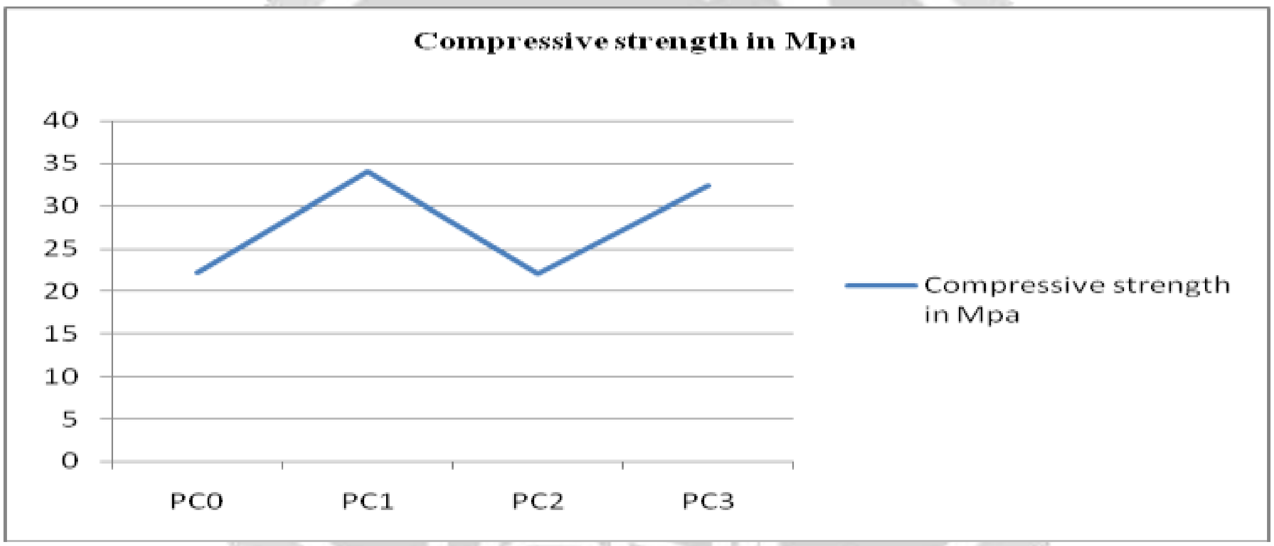
3 Test results of concrete after exposure to 400^{0}C

Mix	Addition of fiber	Compressive strength in Mpa
PC0	No	30.01
PC1	1% steel	38.62
PC2	0.22% PP	28.20
PC3	1%steel + 0.22% PP	37.1



4 Test results of concrete after exposure to 600 ^{0}C

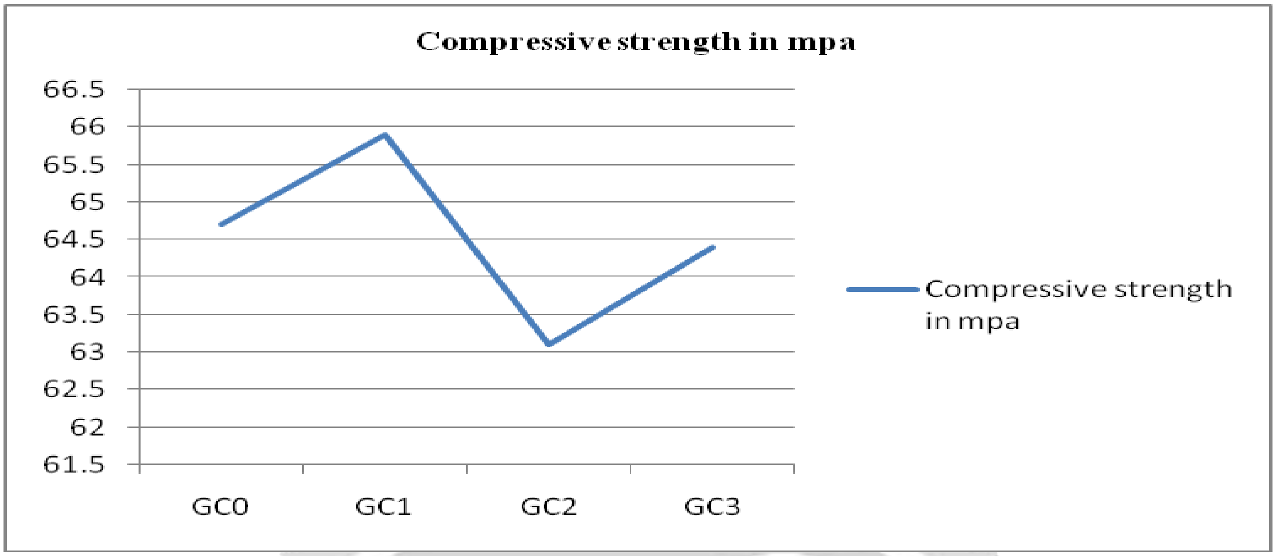
Mix	Addition of fiber	Compressive strength in Mpa
PC0	No	22.08
PC1	1% steel	33.96
PC2	0.22% PP	21.99
PC3	1%steel + 0.22% PP	32.35



Results of same type of mixture (with using GGBS by replacement of cement by 40%)

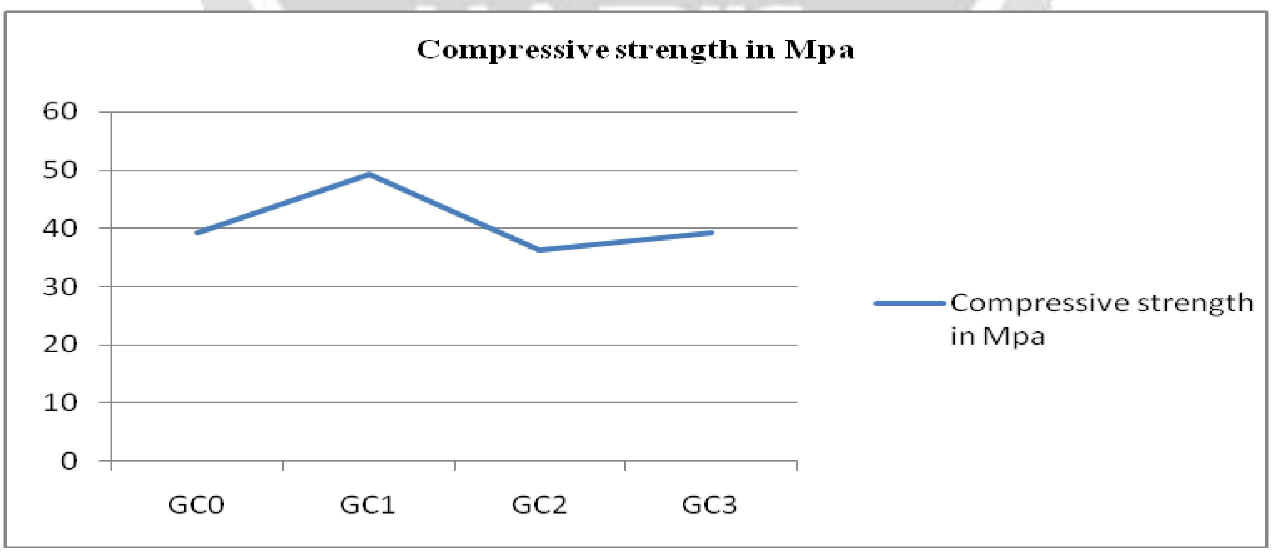
1 Test results for cube of unheated concrete

Mix	Addition of fiber	Compressive strength in Mpa
GC0	No	64.7
GC1	1% steel	65.9
GC2	0.22% PP	63.1
GC3	1%steel + 0.22% PP	64.4



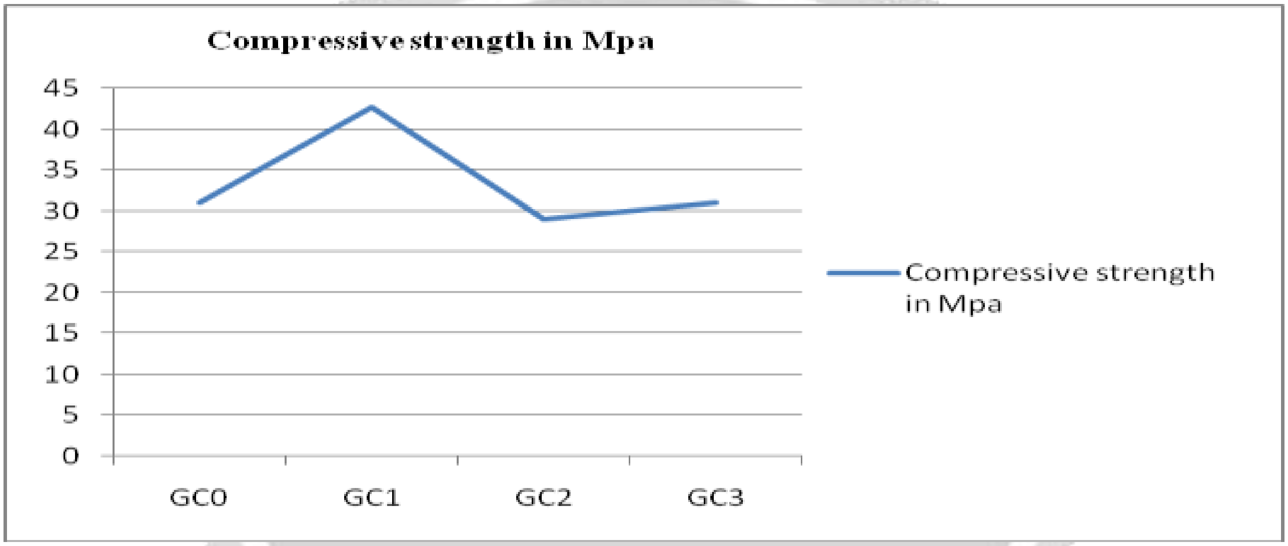
2 Test results of concrete after exposure to 200 ^{0} C

Mix	Addition of fibre	Compressive strength in Mpa
GC0	No	39.2
GC1	1% steel	49.28
GC2	0.22% PP	36.19
GC3	1%steel + 0.22% PP	39.2



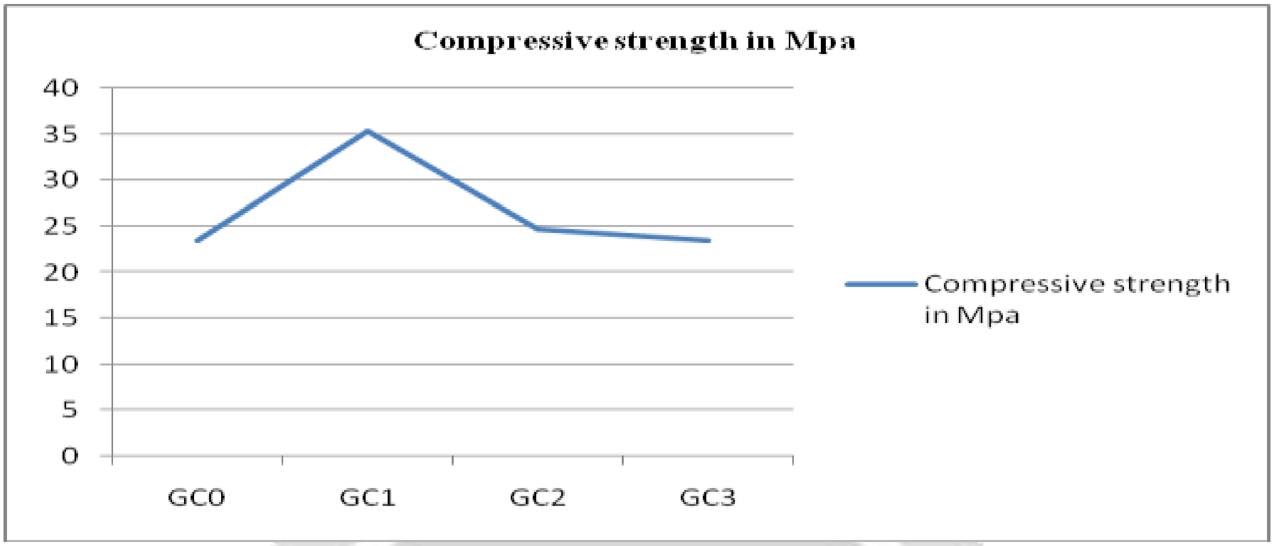
3 Test results of concrete after exposure to 400 ^{0} C

Mix	Addition of fibre	Compressive strength in Mpa
GC0	No	31.02
GC1	1% steel	42.72
GC2	0.22% PP	29.07
GC3	1%steel + 0.22% PP	31.02



4 Test results of concrete after exposure to 600 ^{0}C

Mix	Addition of fibre	Compressive strength in Mpa
GC0	No	23.41
GC1	1% steel	35.28
GC2	0.22% PP	24.62
GC3	1%steel + 0.22% PP	23.41



5. CONCLUSION:

The following conclusions can be drawn from the results:-

1) The addition of polypropylene fibre does not play a vital role in compressive strength. Pp fibre get melt as its melting point is 160 ̊c.
2) Steel fibres are seen to be useful in minimizing the damage effect of high temperature. pp fibre has a negative effect.
3) In addition, it can be concluded that as temperature increases the colour of concrete changes: by knowing that certain colours correspond with specific temperature ranges, the temperature of fire can be estimated.
4) GGBS can be used as one of the alternative material for the cement.
5) Higher strength development is due to filler effect of GGBS and properties of steel fiber.
6) The partial replacement of cement by GGBS, not only provides the economy in construction but also facilitates successful utilisation of the GGBS which is generated in huge quantities from the steel industries.

6. REFERENCES:

- Performance of high strength concretes at elevated temperatures M. Bastami ∗ , A. Chaboki-Khiabani, M. Baghbadrani, M. Kordi
- High Strength Polypropylene Fibre Reinforcement Concrete at High Temperature Farhad Aslani* and Bijan Samali, Centre for Built Infrastructure Research, School of Civil and Environmental
- Lau A, Anson M. Effect of high temperatures on high performance steel fiber reinforced concrete. Cement and Concrete Research. 2006; 36(9):1698–707.
- Impact of high temperature on different combinations of fiber reinforced concrete s. peskova*, czech technical university, czech republic p.p. prochazka, asociation of czech concrete engineers, czech republic.
- Indian Standard (IS). (1999) ―Recommended guidelines for concrete mix design.‖ IS10262-1982, New Delhi., INDIA.
- International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 4, Issue 8, August 2014)

IS CODES

IS 516:1959: Method of test for strength of concrete

IS 10262:2009: Code for concrete mix design

IS 456: Plain and Reinforced concrete code of practice