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Study of High Performance Concrete by Using Fibers

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Abstract:- The concrete which remains reinforced with fibers exhibits the tensile strength which is high at 20^{0C}. After subjecting the specimens to 400^{0C} it was observed that the tensile strength gets reduced. High performance concrete specimens subjected to 600^{0C} show the lowest tensile strength among all the specimens. With the increase in construction of high growth buildings, High performance concrete with increased toughness and durability properties will be of great material in construction industry. To know about the enhancement in strength and resistance to temperature after fiber addition, study of mechanical properties is needed. High Performance High Strength Concrete tends to create shrinkage cracks, so that the study of durability properties is needed.

Keywords:- *Course Aggregate, Glass Fiber, Hooked Steel Fiber, Polyester Fiber, Cement, Water, Fine Aggregate, Super Plasticizer.*

I. INTRODUCTION

Concrete is the most widely used substantial in the construction industry. Concrete is generally made of primary binding material which is cement, fine aggregate, coarse aggregate and water. Concrete is a durable and versatile construction material. It is not only Strong, economical and takes the shape of the form in which it is placed, but it is also aesthetically satisfying Concrete is durable in compression and weak in tension. In the case of high rise buildings, the ordinary concrete leads to bigger members in the structure, which is uneconomical and space consuming. Increase in construction of high rise buildings has led to the development of advanced concrete with higher strength and performance.

American Concrete Institute defines High Performance Concrete as “A concrete which meets special presentation and uniformity supplies that cannot always be achieved regularly by using only conservative materials and normal mixing, placing and curing practices”. The latest research has brought about much technological advancement in all areas of construction, including construction materials, construction methods, interior designing, etc. High Performance concrete is the latest development in the construction materials. It also utilizes the waste products or by products of industrial processes such as fly Ash, Silica Fume, Ground Granulated Blast Furnace Slag (GGBS) and Metakaolin. The primary difference between the ordinary and high performance concrete relates to the compressive strength that refers to the maximum resistance of a concrete sample to the applied pressure. The high performance concrete has to be designed by ACI (American Concrete Institute) 211 methods. High Performance Concrete has very fine microstructure than the normal concrete and exhibits much higher durability, excellent environmental resistance and higher compressive strength. But the improved microstructure results in significant increase in brittleness. Due to high hydration rate the high performance concrete tend to develop more plastic shrinkage cracks. The Concrete with compressive strength more than 60 MPa is High Performance Concrete (HPC).

High Performance Concrete is mostly used in high rise buildings, massive construction to resist the load. High performance concrete is called so on the basis of its high compressive strength measured at given age, durability properties and environmental resistance. HPC’s are often used in the construction of high load bearing columns and for many products in precast plants. High Performance Concrete is suitable for high increase structures, especially in earthquake prone areas. In adding, prestressed bridge building requires high compressive strength important to wider spans and slender bridge sizes. Furthermore the outstanding mechanical characteristics of high performance existing is utilized in structures exposed to mechanical and chemical loading like industrial floors, traffic areas, offshore constructions, sewage treatment plants and manufacturing constructions like hydro power plants, cooling towers, etc.

A. Need For Research

- With the increase in construction of high rise buildings, Tall presentation concrete with increased toughness and durability properties will be of great material in construction industry.
- To know about the enhancement in strength and resistance to temperature after fibre addition, study of mechanical properties is needed.
- High Performance High Strength Concrete tends to create shrinkage cracks, so that the study of durability properties is needed.

B. Objectives

- To develop a High Performance Hybrid Fibre Strengthened Concrete for a target compressive strength of 80MPa.

- To investigate the mechanical properties of high performance hybrid fibre reinforced concrete under elevated temperature.
- To study the durability properties of high performance hybrid fibre reinforced concrete under elevated temperature.

C. Scope

- Development of high presentation hybrid fiber composite concrete will mitigate the brittleness of concrete and will make it more tough and ductile.
- HPC decreases the spalling effect of concrete when subjected to temperature
- To test the specimen for compression test, split tensile test, flexure test and compare the results for various ranges of temperature.
- To test the concrete specimen for water absorption test and Rapid Chloride Permeability test and compare the results.

II. LITERATURE SURVEY

Albert (2009) calculated the mechanical properties of Fiber Reinforced Cement Composites. The research showed that the polypropylene fibres are superior to other commercially available fibres such as alkali resistant fibres and stainless steel fibres. The addition of 2% of polypropylene fibres (by mass) to high-performance concrete did not have important effect on the compressive and splitting tensile strength of concrete. Under the thermal treatment at 200º C, the penetrability of the fibre reinforced high-performance concrete was better than that of the control high-performance concrete because of the fibre melting during heating up.

Poon et al. (2004) studied the compressive behavior of fibre reinforced high performance subjected to elevated temperatures. The usage of Silica fume resulted in reduced degradation of compressive strength after exposure to elevated temperature. Steel fibres increase the toughness of concrete more than that of Polypropylene fibres and it is same when it is exposed to elevated temperatures. High Performance Concrete mixes retained 45% of their compressive strength after exposure to 600 degree Celsius and this was further reduced to only 23% after exposure to 800 degree Celsius. The use of Metakaolin at a replacement level of 20% of cement resulted in higher compressive strength than the use of Silica fume at 10% but more brittle stress strain responses. Steel fibres approximately doubled the toughness of the concrete.

Kadri et al. (2012), studied the compressive strength of High-Performance Concrete. The study showed that the 20% replacement of cementitious material with silica fume is the optimum replacement and will increase the compressive strength about 15%. The compressive strength of concrete incorporating 20% of Silica fume is more than 30% of Silica fume. The increase of compressive strength of silica fume concrete depends much more on reduction of water/binder ratio than the replacement of silica fume with cement.

Bobby Mathew et al. (2015), studied the tensile properties of high strength concrete reinforced with single steel fibre. The experiments were carried out on concrete with different fibre combination and controlled concrete specimen. The study concluded that the compressive strength increased by 7.47% when fibres are added, split tensile strength increased by 33% upon addition of 0.5% fibre volume and 46.5% when 1% of fibre is added. The direct tensile strength is increased by 12.18% when 0.5% of fibres are added and 23.64% when 1% of fibre content is available in the concrete mix.

Abdullah Huzeyfe Akca (2013), studied the durability properties of high performance concrete under elevated temperature. The study showed that explosive spalling of specimen occurs when unprotected to 600˚C and spalling began at about 500˚ C. The density of cracks decreased from high heat exposed surface to inside of the samples, maybe due to the fact that comparatively lower temperatures were experienced inside the specimens when compared to outer surfaces. The samples heated to 900˚C were completely broken after 3 days. Only the specimens exposed to water one day after heating to 900˚ C were not crumbled.

Tomas Drzymala (2017), studied the physical and mechanical properties of high performance concrete exposed to the effect of high temperature. Heating at 300˚ c increases the compressive strength of high-performance concrete in relation to the initial strength determined at 20˚ C, which was observed on all the tested types of high-performance concrete air-entrained, fibre re-inforced and reference specimens. At 450º C compressive strength reduced in all cases in relation to the value resolute after heating at 300º C, though it did not drop below the initial value. Heating at 600º c reduced the compressive strength below the value determined on unexposed specimens in all cases with the maximum drop to 65% of the initial value noted for the fiber-reinforced concrete.

Song et al.(2014) studied the mechanical properties of high strength fibre reinforced concrete (HSFRC) by that the brittleness with low tensile strength and strain capacities of high strength concrete (HSC) can be reduced by steel fibre. The study of high strength hybrid fibre reinforced concrete is reported that the use of steel fibre in concrete decreases the workability of concrete but increases spilt tensile strength, modulus of elasticity and Poisson's ratio.

Venkatesan et al.(2015), studied the flexural behavior of high strength steel fiber reinforced concrete beams. This paper presents the results of experimental studies conducted to examine the effectiveness of steel fiber in enhancing, flexural capacity of high strength beams. Different fiber volume fractions (0.25%, 0.5%) were adopted and were compared with a control beam with 0% fiber. The results showed that beams with 0.25% fiber volume fraction exhibited an increased strength, sufficient ductility, toughness and composite action until failure.

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Sivakumar et al. (2007), studied the mechanical properties of high strength concrete reinforced with metallic and non metallic fibres. The study investigates the mechanical properties such as compressive strength, tensile strength, flexural toughness and flexural strength of concrete reinforced with hybrid fibre combination of steel polypropylene, steel glass and steel polyester. The metallic fibre contributes towards the energy absorption mechanism and the non metallic fibres are the reason for delaying the formation of micro cracks. The combined use of Polypropylene fibres and steel fibres showed little benefits compared with the use of steel fibres only. The steel polypropylene hybrid fibre combination has performed in all aspects than other combinations and mono fibres. Glass fibres performed the worst with respect to toughness owing to the reason of getting pulled out due to their short lengths. The flexural toughness got decreased when the percentage of nonmetallic fibres got increased. Increased fibre availability in hybrid combination along with the ability of nonmetallic fibres to bridge the micro cracks could be the reason for enhancement of the mechanical properties when hybrid combination of fibres are used.

III. MATERIALS AND METHODOLOGY

A. Cement

The 53 grade Ordinary Portland Cement was used for this study. Cement is the most important element in the concrete. Some of the important factors that plays a major role in selection of a cement is compressive strength, fineness of the cement, heat of hydration, alkali content, tri calcium aluminates (C_3A) satisfied, tri calcium sulphate (C_3S) content, di calcium silicate (C_2S) content, etc. It is also essential to ensure the comparison of mineral and chemical admixtures with binder content. Ordinary Portland cement is available in 33, 43 and 53 grades. For the current study, OPC 53 grade confirming to IS 12269-1987 was selected. Cement should be dry, fine and free from lumps. While storing cement, avoid possible contact with moisture. The cement bags must be stacked in such a manner that the older bags are used prior to the newly stacked bags, so that the wastage of cement due to stacking is avoided. Store the cement away from exterior walls, off damp floors. Cement’s specific gravity is calculated experimentally and it is 3.15.

B. Silica Fume

Silica Fume is gotten as the item from the creation of silicon metals and combinations of ferrosilicon. The most sparing utilization of Silica rage is as mineral admixture in concrete. As a result of its synthetic properties and physical appearance, it is an extremely proficient pozolana. Concrete blended with silica seethe have great mechanical and strength properties. Silica rage is accessible in advertise from different providers of bond admixtures and added to concrete during mixing. Specific Gravity of the silica smolder is 2.2.

C. Fine Aggregate

Fine aggregate given for concrete must be appropriately graded while collection of materials to obtain minimum void ratio and should not consists of pernicious materials like silt content, clay and chloride contamination, etc. Classifying of Fine aggregate should be such that it does not increase in water demand for the concrete and should give voids so that the fine cementitious elements fill the voids. Hence it is desirable to use coarser change of fine aggregate with high fineness modulus for making practical and durable concrete. Specific gravity of fine aggregate used for this study is 2.65. Sieve analysis grading is shown in figure 1.

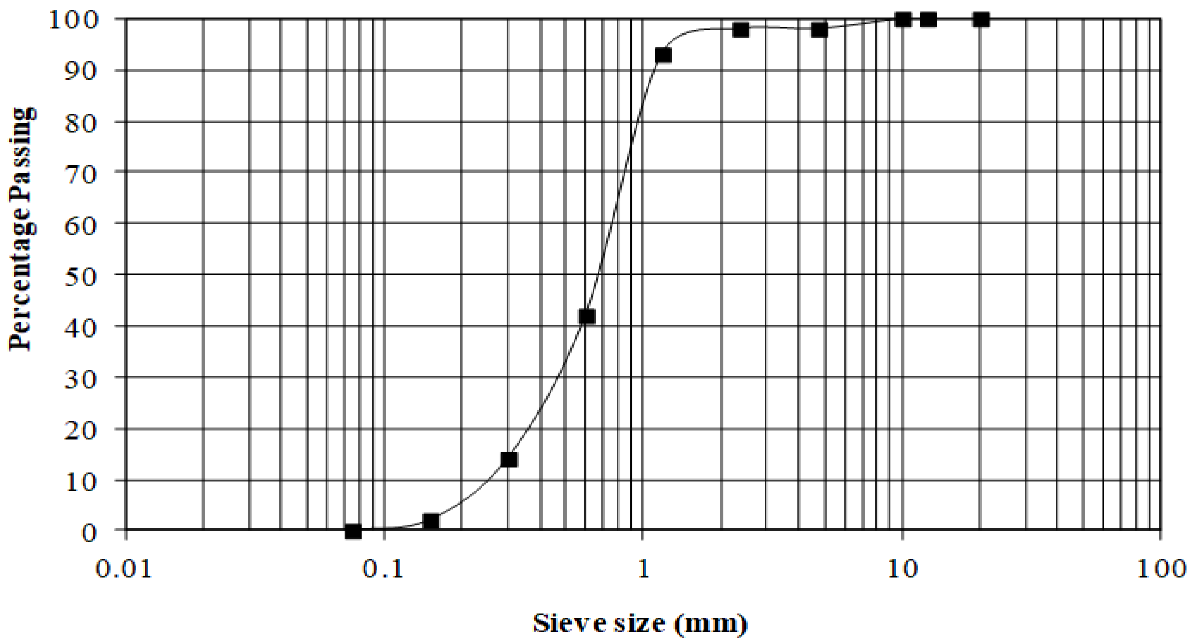

Fig 1:- Sieve analysis of River Sand

D. Coarse Aggregate

Uncrushed gravels or stones which are the result of natural disintegration of rocks are known as coarse aggregates. Coarse aggregates are the stones that are retained in a 4.75 mm sieve. Coarse aggregate is the material which is least porous and strongest material in the concrete. Chemically it is a stable material. coarse aggregate in concrete will reduce the drying shrinkage up to the more extent and additional dimensional changes occurs on account of moisture present in concrete. Coarse aggregate helps concrete to make it impermeable provided that the mix is suitably designed. Ordinary blue granite crushed stone confirming to IS 383-1997 was used in this study as coarse aggregate. Optimal size of the coarse aggregate of range 10-12.5 mm was adopted. The coarse aggregate generally exhibits the qualities of high crushing strength as a good building stone, low absorption and less porosity. Specific Gravity of the coarse aggregate is 2.8. Figure 2 represents the Sieve Analysis of coarse aggregate.

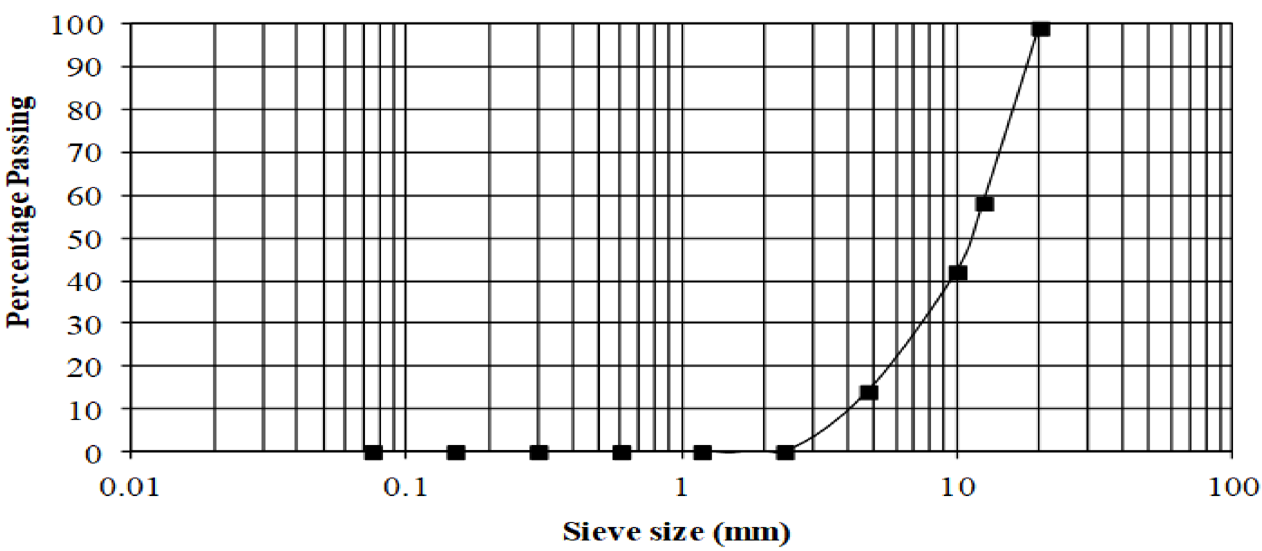

Fig 2:- Sieve Analysis of Coarse Aggregate

E. Water

Water remains the foremost important element in the building whereas the people ignore excellence aspect of the element. The water is used for preparing cement mortar, mixing concrete, curing of buildings etc. during the time of construction work. The amount and excellence of water will have an adverse effect on strength parameters of mortar and cement material used in construction. Water is an important ingredient that effectively takes part in chemical reaction with cement to frame the hydrated products. The strength of concrete mainly depends up on the binding action of hydrate gel. The water binder ratio will play a major role in influencing the mechanical and durability properties of concrete.

F. Superplasticizer

Super plasticizer is chemicals that can be adapted for the concrete to increase the flow of concrete that is workability without increase in water content. Thus it enables the use of low water binder ratio and produces High Strength Concrete. Surface active agents are the principal elements in super plasticizer. During mixing, these agents react with cement particles and give them a charge which is negative which leads to the movement of particles and results in uniform dispersion of cement articles more in nature. With the use of Super plasticizer, concrete can be effectively obtained with even low water binder ratio as 0.2. The potential applied to the particles in cement by the Super plasticizer is given by the charge implied to the particles and it is called zeta potential. In this study, Super plasticizer with solid content of 50% and specific gravity of 1.12 is adopted.

G. Fibres

Fibres used in this study are :

- Hooked steel fibre
- Glass fibre
- Polyester fibre

Hooked Steel fibres are of 35mm length and 0.55mm diameter was adopted in this study. Polyester fibre of size 6mm length and 25-30µm diameter was used in this project. Glass fibres was adopted in this study. Hooked steel increases the ductility of the concrete. Glass fibres acts as thermal insulator for the concrete. Polyster fibres also have good resistance towards the temperature effects. Physical properties of fibres are listed in Table 3.1.The figures of hooked steel, Glass fiber and polyester fibres are shown below.

Property	Hooked Steel Fibre	Glass Fibre	Polyester Fibre
Length (mm)	35	13	6
Diameter (mm)	0.55	0.03	0.025
Aspect ratio	50	82	240
Density (g/cc)	7.85	2.46	1.34
Tensile strength	1450MPa	4890 MPa	600 MPa

Table 1:- Physical Properties of Fibres

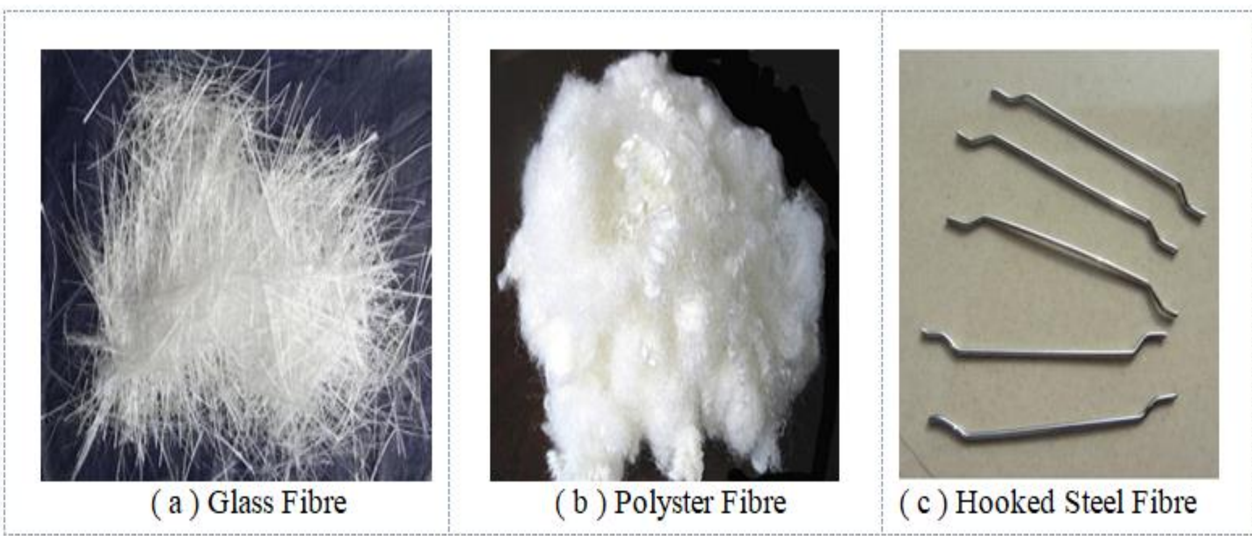

Fig 3:- Fibres Used In This Study

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H. Methodology

The methodology for the project is given in Figure 4.

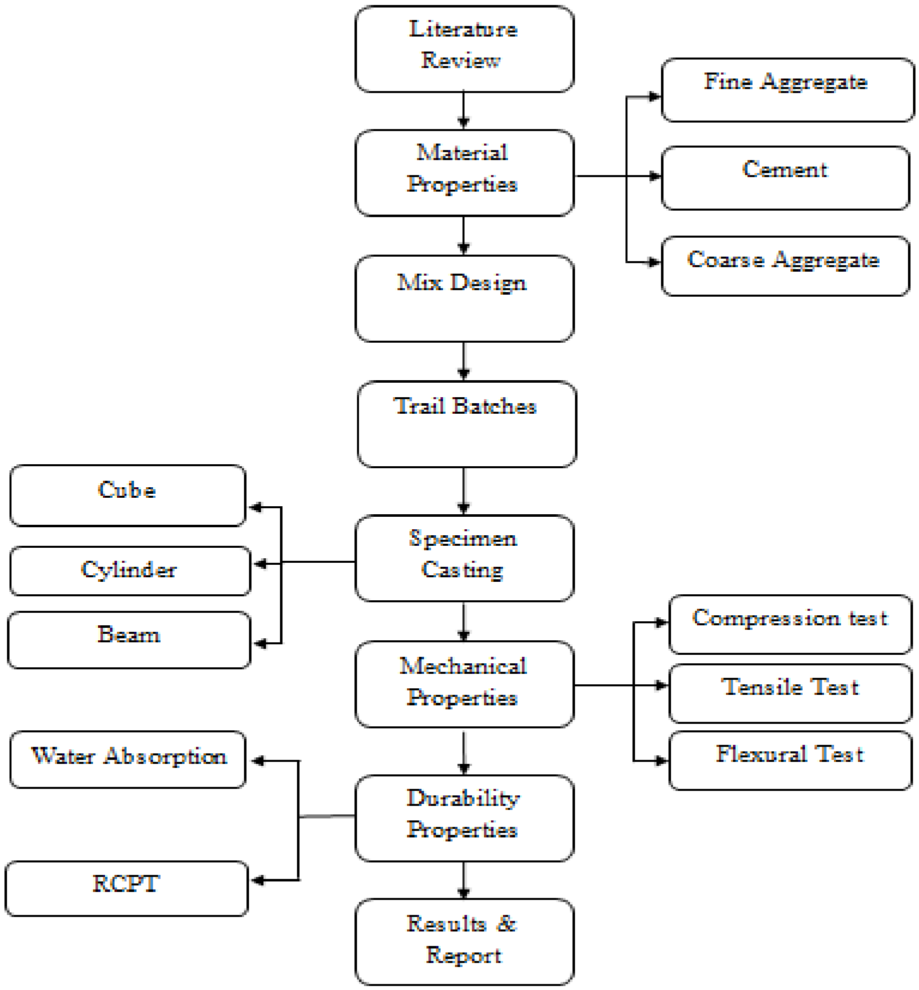

Fig 4:- Flowchart for Mix Design Process

Materials	Content
Binder Content	600 kg/m^3
Cement	510 kg/m^3
Silica Fume	72 kg/m^3
Fine Aggregate	683 kg/m^3
Coarse Aggregate	1050 kg/m^3
Water Content	180 l/m^3
Super plasticizer	13.37 1/m^3

Table 2:- Material proportion of Mix

MIX DESIGNATION	HOOKED STEEL (%)	GLASS FIBRE (%)	POLYESTER FIBRE (%)
MIX 1	0%	0%	0%
MIX 2	0.5%	0.25%	0.25%
MIX 3	0.5%	0.15%	0.15%
MIX 4	0.25%	0.25%	0.25%

Table 3:- Mix Details and Fiber Proportions

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IV. RESULTS AND DISCUSSION

❖ *Tests Conducted*

A. *Compressive Strength Test*
B. *Split Tensile Strength Test*
C. *Flexural Strength Test*
D. *Rapid Chloride Penetration Test*

A. *Compressive Strength*

Compressive strength was the most important parameter in concern to the mechanical property that should be checked for the high performance concrete. The test was carried out as per IS 1199: 1959. High Performance Concrete mixes retained 45% of their compressive strength after exposed to 600 degree Celsius. [1]. Figure shows the compressive strength results for different types of mixes under different temperatures.

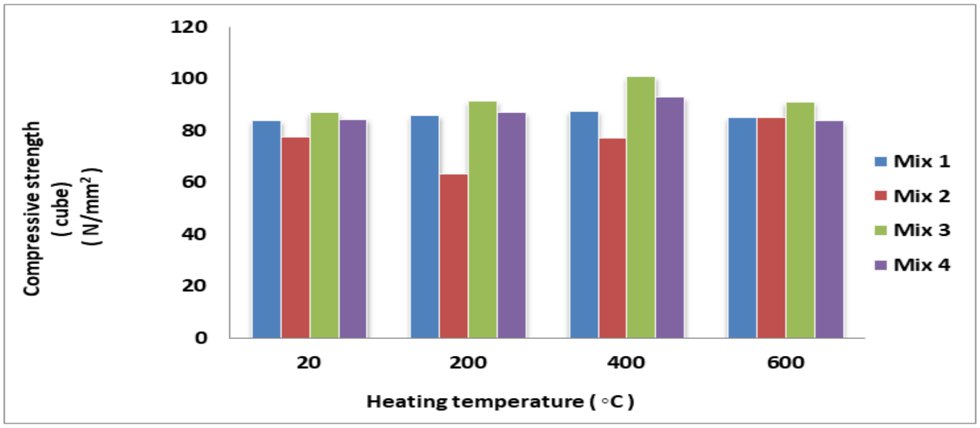


Fig 5:- Compressive strength of high performance concrete under elevated temperature

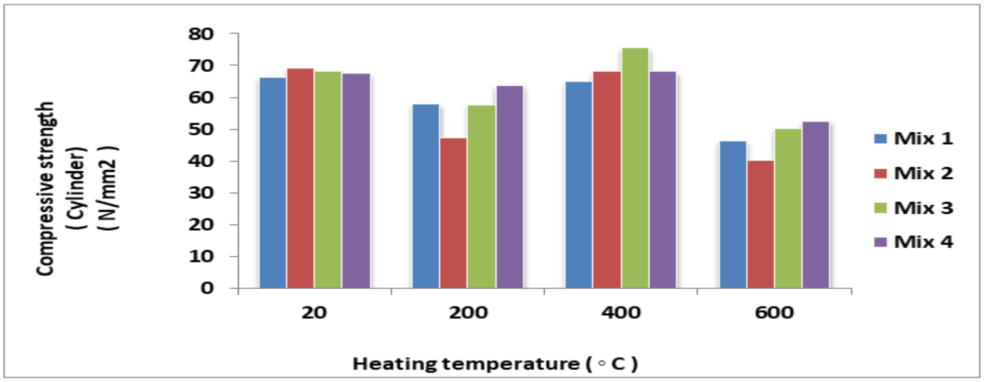


Fig 6:- Compressive strength of high performance concrete under elevated temperature

Fig 7:- Compressive strength test

B. Split Tensile Strength

The split tensile strength test was lead on the specimens of size 100mm diameter × 200mm length cylinders. The tensile strength of high performance concrete reduces when there is a increase in temperature. The ultimate compressive strength at 400 degree Centigrade and 600 degree Centigrade speaks to 60% & 35% respectively compared to strength obtained initially while the ultimate tensile strength 60% & 30% respectively. This fall is for the most part caused by the structure of specimen harmed by the cracks and expanded porosity [3]. The tests were conducted on 28th day & mentioned in Fig 7.

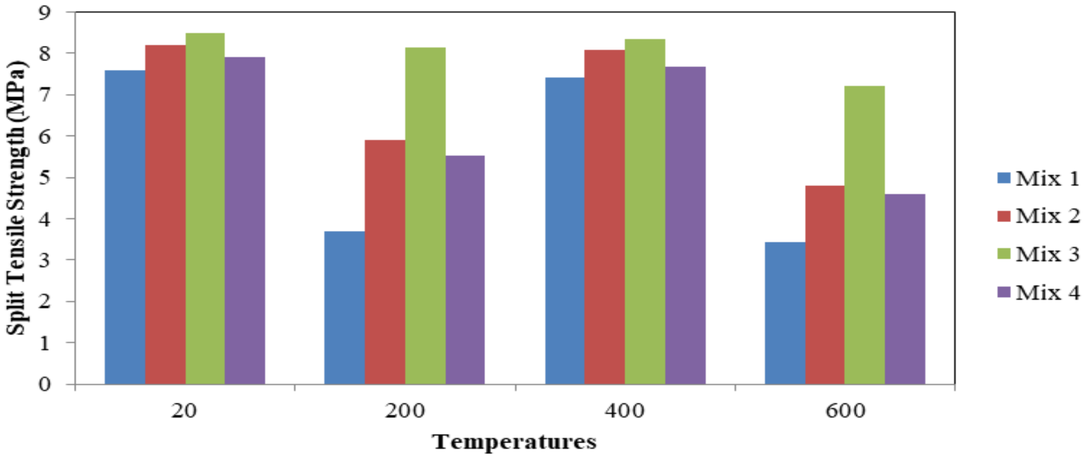


Fig 8:- Split tensile strength of high performance concrete under elevated temperature.

Fig 9:- Split tensile strength

C. Flexural Strength

A concrete beam of size (100×100×500mm) was tested for flexural strength. Tests were done confined to IS 1199:1959. The tests were conducted on 28th day are shown in fig 5. . The flexural quality more often than not fluctuates in between 8 to 10% of the compressive strength compared to ordinary concrete. Whereas when comes to the flexural strength of high strength concrete will be less when compared. The average flexural strength will be normally about 6.23 percentage of compressive strength after the curing period of 28 days.

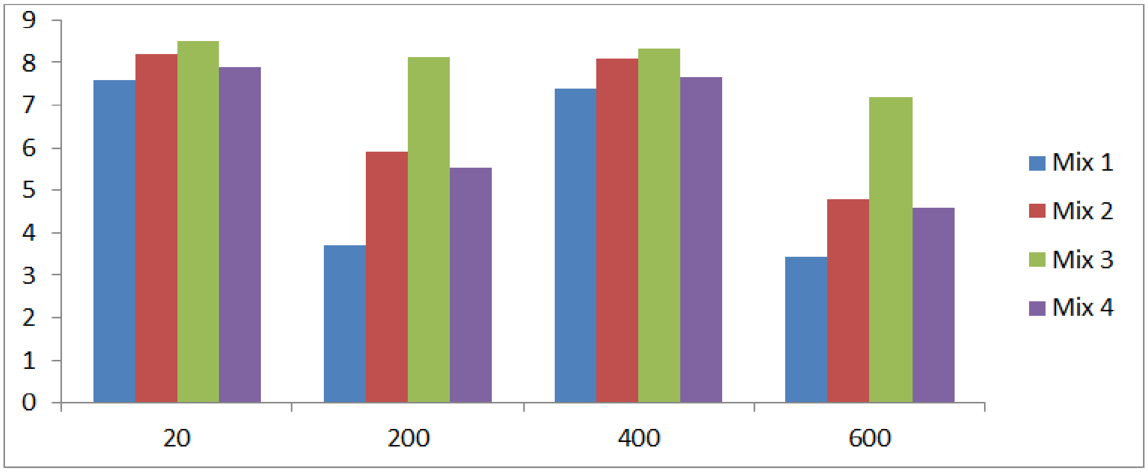


Fig 10:- Flexural Strength of High Performance Concrete under Elevated Temperature

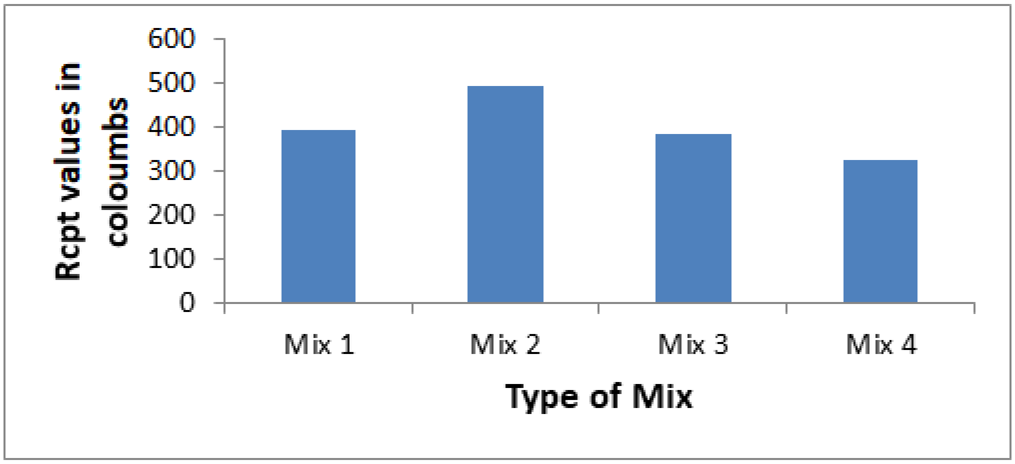

Fig 11:- Flexural strength test

D. Rapid Chloride Penetration Test

The infiltration of the chloride is exceptionally unsafe when goes to the strength of cement. Quick chloride infiltration test (RCPT) is one of the technique for assessing the solidness execution of cement. The test was completed as per ASTM C1202:2012. The sturdiness properties of elite cement under raised temperature. The examination demonstrated that dangerous spalling of example happens when presented to 600˚C and spalling started at roughly 500˚ C. The thickness of breaks diminished from high temperature presented surface to within the examples, likely because of the way that generally bring down temperatures were experienced inside the examples when contrasted with external surfaces. The examples warmed to 900˚C were totally broken down following 3 days. Just the examples presented to water one day in the wake of warming to 900˚ C were not broken down [2]. The test was led following 28 days and whereas the outcomes are presented in the underneath table.

Type of mix	Days	RCPT values (coulombs)	Chloride Permeability As Per ASTM C 1202
Mix 1	28	393	Very low
Mix 2		496	Very low
Mix 3		385	Very low
Mix 4		324	Very low

Table 4:- RCPT results for high performance concrete



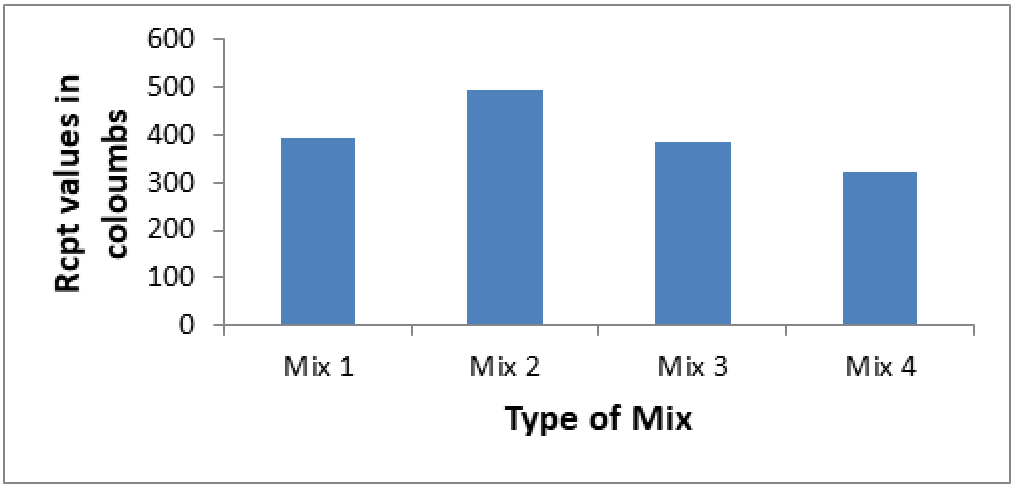


Fig 12:- RCPT values of High performance concrete

V. CONCLUSIONS

- The Compressive strength value of high performance concrete specimens is increased by heating at 200 degree Centigrade when the specimens compared at 20 degree Centigrade. When comparing the specimens exposed at 400 degree Centigrade the compressive strength value decreased to the initial value determined at 20 degree Centigrade.
- By the addition of steel fiber the mechanical properties of Hybrid Fiber Reinforced concrete are increased.
- When the concrete specimens exposed to ambient elevated temperature, there was a change in normal relationship of the compressive strength and the split tensile strength.
- Different percentage of fibres was used for this study to see the effect on high performance concrete under elevated temperature.
- When the concrete specimens are exhibited to the high temperature at 400 degree Centigrade onwards the specimens observed some properties like cracks on the surface of the specimen, the color changes & more brittle in nature
- When the concrete specimens are subjected to 600 degree Centigrade, the mechanical properties of HPC which are split tensile strength and compressive strength are totally reduced.

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