STUDY ON STRENGTH PROPERTIES OF POLYPROPYLENE FIBRE REINFORCED CONCRETE

by Sabin Rai

STUDY ON STRENGTH PROPERTIES OF POLYPROPYLENE FIBRE REINFORCED CONCRETE
A PROJECT

Submitted in partial fulfilment of the requirements for the award of the degree of

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IN

CIVIL ENGINEERING

Under the supervision of

Dr. Ashok K. Gupta

Professor and Head of Department

By

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To

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT SOLAN – 173 234

HIMACHAL PRADESH

INDIA

July, 2017

DEDICATED TO MY FAMILY

CERTIFICATE

This is to certify that the work which is being presented in the project title **"Study On Strength Properties Of Polypropylene Fibre Reinforced Concrete"** in partial fulfilment of the requirements for the award of the degree of Bachelor of technology and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Sabin Rai** bearing enrolment number **131606** during a period from January 2017 to July 2017 under the supervision of Dr. Ashok K. Gupta Professor and Head of Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date: - ....

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Acknowledgement

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Sabin Rai (131606)

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d	Diameter, depth (mm)
l	Length, mm
P	Load (KN)
R	Flexural Strength
T	Tensile Strength
Vf	Volume Fraction
W	Weight (gm)
Φ	Diameter (mm)
ASTM	American Society of Testing of Materials
BIS	Bureau of Indian Standards
CTM	Compression Testing Machine
UTM	Universal Testing Machine
FRC	Fibre Reinforced Concrete
RCC	Reinforced Cement Concrete, Roller Compacted Concrete
PPC	Portland Pozolana Cement
OPC	Ordinary Portland Cement
PPF	Polypropylene Fibres
PPFRC	Polypropylene Fibre Reinforced Concrete

Abstract

This project involves discovering how the addition of fibres in plain concrete mix of M60 grade affects its strength properties. The Strength properties include compressive strength, split tensile strength and flexural strength. The goal of this project is to show that an addition of fibres in plain concrete mix significantly improves its strength. This has been done by casting of numerous concrete cubes, cylinders and beams. The fibre used was Polypropylene fibres. Upon experimenting on this, we have found out that strengths, i.e. compressive strength, split tensile strength and flexural strength has improved significantly.

Polypropylene is a synthetic hydrocarbon polymer, the fibre of which is made using extrusion processes by hot drawing the material through a die. Its use enables reliable and effective utilization of intrinsic tensile and flexural strength of the material along with significant reduction of plastic shrinkage cracking and minimizing of thermal cracking.

The project deals with the effects of addition of various proportions of polypropylene fibre on the properties of concrete. An experimental program was carried out to explore its effects on compressive, tensile and flexural strength of concrete.

We can thus conclude that fibres impart energy absorption, toughness and impact resistance properties to fibre reinforced concrete material and these characteristics in turn improve the fracture and fatigue properties of fibre reinforced concrete.

CHAPTER 1

INTRODUCTION TO FIBRE REINFORCED CONCRETE

1.1 General

Present civil engineering has pioneered in the construction of high rise buildings and mega structures. However the cities and world at large is facing the stainability of the structures and cities problem and new ways of construction materials without compromising the strength and durability of structures is primal. Recently engineers are building sustainable cities with use of fibres in construction of structures. Fibre concrete is getting its popularity and hoping it's the answer to unsustainable structures.

Concrete is composite material containing cement, water, fine aggregates and coarse aggregates. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. This stone like material is a brittle material which is strong in compression but very weak in tension. This weakness in the concrete makes it to crack under small loads, at the tensile end. These cracks gradually propagate to the compression end of the member and finally, the member breaks. The formation of cracks in the concrete may also occur due to the drying shrinkage. These cracks are basically micro cracks. These cracks increase in size and magnitude as the time elapses and the finally the concrete fails altogether.

The formation of cracks is the main reason for the failure of the concrete. To increase the tensile strength of concrete many attempts have been made. One of the successful and most commonly used methods is providing steel reinforcement. Steel bars, however, reinforce concrete against local tension only. Cracks in reinforced concrete members extend freely until encountering the bar. Thus need for multidirectional and closely spaced steel reinforcement arises. That cannot be practically possible. Fibre reinforcement gives the solution for this problem.

So, to increase the tensile strength of concrete, a technique of introduction of fibres in concrete is being used. These fibres act as crack arrestors and prevent the propagation of the cracks. These fibres are uniformly distributed and randomly arranged. This concrete is named as fibre reinforced concrete.

The main reasons for adding fibres to concrete matrix are to improve the post cracking response of the concrete, i.e., to improve its energy absorption capacity and apparent ductility and to provide crack resistance and crack control, Also, it helps to maintain structural integrity and cohesiveness in the material. The initial researches combined with the large volume of follow up research have led to the development of a wide variety of material formulations that fit the definition of Fibre Reinforced Concrete. There are many ways to minimize the failure of the concrete structures made of steel reinforce concrete. The custom approach is to adhesively bond fibre polymer composites onto the structure.

This also helps to increase the toughness and tensile strength and improve the cracking and deformation characteristics of the resultant composite. But this method adds another layer, which is prone to degradation. These fibre polymer composites have been shown to suffer from degradation when exposed to marine environment due to surface blistering. As a result, the adhesive bond strength is reduced, which results in the de-lamination of the composite.

The principal reason for incorporating fibres into a cement matrix is to increase the toughness and tensile strength, and improve the cracking deformation characteristics of the resultant composite. In order for fibre reinforced concrete (FRC) to be a viable construction material, it must be able to compete economically with existing reinforcing systems. Only a few of the possible hundreds of fibre types have been found suitable for commercial applications.

1.2 Fibre Reinforced Concrete

Fibre reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. So we can define fibre reinforced concrete as a composite material of cement concrete or mortar and discontinuous, discrete and uniformly dispersed fibre. Fibre is discrete material having some characteristic properties. The fibre material can be anything. But not all will be effective and economical.

Some fibres that are most commonly used are:

a) Glass
b) Carbon
c) Natural
d) Steel and
e) Synthetic

Glass fibre is a recently introduced fibre in making fibre concrete. It has very high tensile strength of 1020 to 4080Mpa. Glass fibre concretes are mainly used in exterior building façade panels and as architectural precast concrete. This material is very good in making shapes on the front of any building and it is less dense than steel. The glass fibres used are with modulus of elasticity 72 GPa, Filament diameter 14 microns, specific gravity 2.68, length 12 mm and having the aspect ratio of 85. The number of fibres per kg is 212 million fibres.

Use **of carbon fibre** is not a developed process. But it has considerable strength and young's modulus. Also investigations have shown that use of carbon makes the concrete very durable. The study on the carbon fibres is limited. Mainly used for cladding purpose.

Natural fibres are low cost and abundant. They are non-hazardous and renewable. Some of the natural fibres are bamboo, jute, coconut husk, elephant grass. They can be used in place of asbestos. It increases toughness and flexural strength. It also induces good durability in concrete.

Steel fibre is one of the most commonly used fibres. Generally round fibres are used. The diameter may vary from 0.25 to 0.75mm.The steel fibre sometimes gets rusted and lose its strength. But investigations have proved that fibres get rusted only at surfaces. It has high modulus of elasticity. Use of steel fibres makes significant improvements in flexure, impact and fatigue strength of concrete. It has been used in various types of structures.

Fibres are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion, and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete, and so cannot replace moment–resisting or structural steel reinforcement. Indeed, some fibres actually reduce the strength of concrete.

The amount of fibres added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibres), termed "volume fraction" (V_f). V_f typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fibre length (l) by its diameter (d). Fibres with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fibre's modulus of elasticity is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increasing the aspect ratio of the fibre usually segments the flexural strength and toughness of the matrix. However, fibres that are too long tend to "ball" in the mix and create workability problems.

1.3 History

The use of fibres to increase the structural properties of construction material is not a new process. From ancient times fibres were being used in construction. In late BC, horse hair was used to reinforce mortar. Egyptians used straw in mud bricks to provide additional strength; this process is still prevalent in traditional Bhutanese architecture today. Asbestos was used in the concrete in the early 19th century, to protect it from formation of cracks. But in the late 19th century, due to increased structural importance, introduction of steel reinforcement in concrete was made, by which the concept of fibre reinforced concrete was over looked for 5-6 decades. Later in 1939 the introduction steel replacing asbestos was made for the first time. But at that period it was not successful. From 1960, there was a tremendous development in the FRC, mainly by the introduction of steel fibres. Since then use of different types of fibres in concrete was made.

In 1970's principles were developed on the working of the fibre reinforced concrete. Later in 1980's certified process was developed for the use of FRC. In the last decades, codes regarding the FRC are being developed.

Even today in traditional Bhutanese's architecture and some structures fibre in the form of straws are used to make the mud bricks stronger and more durable.

1.4 Properties of Fibre Reinforced Concrete

Properties of concrete is affected by many factors like properties of cement, fine aggregate, coarse aggregate. Other than this, the fibre reinforced concrete is affected by following factors:

a) Type of fibre
b) Aspect ratio
c) Quantity of fibre and,
d) Orientation of fibre

1.4.1. Type of fibre:

A good fibre is the one which possess the following qualities:

- Good adhesion within the matrix
- Adaptable elasticity modulus (sometimes higher than that of the matrix)
- Compatibility with the binder, which should not be attacked or destroyed in the long term.
- An accessible price, taking into account the proportion within the mix
- Being sufficiently short, fine and flexible to permit mixing, transporting and placing
- Being sufficiently strong, yet adequately robust to withstand the mixing process.

1.4.2. Aspect ratio:

Aspect ratio is defined as the ratio of length to width of the fibre. The value of aspect ratio varies from 30 to 150. Generally the increase in aspect ratio increases the strength and toughness till the aspect ratio of 100. Above that the strength of concrete decreases, in view of decreased workability and reduced compaction.

1.4.3. Fibre quantity:

Generally quantity of fibres is measured as percentage of cement content. As the volume of fibres increase, there should be increase in strength and toughness of concrete. But that doesn't always happen. Usually at optimum fibre content, a maximum value of strength is obtained after which the values decline.

1.4.4. Orientation of fibre:

The orientations of fibres play a key role in determining the capacity of concrete. In RCC the reinforcements are placed in desired direction. But in FRC, the fibres will be oriented in random direction. The FRC will have maximum resistance when fibres are oriented parallel to the load applied.

1.5 Fibre Mechanism

Fibre work with concrete utilizing two mechanisms:

- The spacing mechanism and
- The crack bridging mechanism.

The spacing mechanism requires a large number of fibres well distributed within the concrete matrix to arrest any existing micro crack that could potentially expand create a sound crack. For typical volume of fractions of fibres utilizing small diameter of fibres or micro fibres can ensure the required no of fibres for micro crack arrest.

The second mechanism termed crack bridging requires larger straight fibres with adequate bond to concrete. Steel fibres are considered a prime example of this fibre type that is commonly referred as large diameter fibres or micro fibres.

Plain concrete fails suddenly once the deflection corresponding to the ultimate flexural strength is exceeded; on the other hand, fibre-reinforced concrete continue to sustain considerable loads even at deflections considerably in excess of the fracture deflection of the plain concrete. Examination of fractured specimens of fibre-reinforced concrete shows that failure takes place primarily due to fibre pull-out or de-bonding. Thus unlike plain concrete, a fibre-reinforced concrete specimen does not break immediately after initiation of the first crack. This has the effect of increasing the work of fracture, which is referred to as toughness and is represented by the area under the load-deflection curve. In FRC crack density is increased, but the crack size is decreased.

1.6 Workability

A shortcoming of using fibres in concrete is reduction in workability. Workability of FRC is affected by fibre aspect ratio and volume fraction as well the workability of plain concrete. As fibre content increases, workability decreases. Most researchers limit volume of fibres to 4.0% and aspect ratio to 100 to avoid unworkable mixes. To overcome the workability problems associated with FRC, modification of concrete mix design is recommended. Such modifications can include the use of additives.

1.7 Strength and Durability

The most important contribution of fibre-reinforcement in concrete is not to strength but to the flexural toughness of the material. When flexural strength is the main consideration, fibre reinforcement of concrete is not a substitute for conventional reinforcement. The greatest advantage of fibre reinforcement of concrete is the improvement in flexural toughness.

Fibre-reinforced concrete is generally made with a high cement content and low water/cement ratio. When well compacted and cured concretes containing steel fibres seem to possess excellent durability as long as fibres remain protected by cement paste. Ordinary glass fibre cannot be used in Portland cement mortars and concretes because of chemical attack by the alkaline cement paste.

1.8 Objectives

Today there are different types of fibres are available and are used in concrete widely. Fibres are used mainly to improve the strength properties of concrete. In the present study, following objectives are stipulated:

- To study the change in mechanical properties of M20 and M60 grade concrete.
- To check the suitability of polypropylene fibres to be used as reinforcement in concrete.
- To find the percentage improvement in the mechanical properties of concrete M60 after using polypropylene fibres as reinforcing material.
- To find the optimum fibre content to be used in high strength concrete.

1.9 Introduction of Polypropylene Fibres

Polypropylene fibres were first suggested as an admixture to concrete in 1965 for the construction of blast resistant buildings for the US Corps of Engineers. The fibre has subsequently been improved further and at present it is used either as short discontinuous fibrillated material for production of fibre reinforced concrete or a continuous mat for production of thin sheet components. Since then the use of these fibres has increased tremendously in construction of structures because addition of fibres in concrete improves the toughness, flexural strength, tensile strength and impact strength as well as failure mode of concrete. Polypropylene twine is cheap, abundantly available, and like all manmade fibres of a consistent quality.

(a) (b) (c)

Fig.1.9.(a), (b) and (c). Polypropylene fibres strands

1.9.1 Properties of Polypropylene Fibres

The raw material of polypropylene is derived from monomeric C3H6 which is purely hydrocarbon. Its mode of polymerization, its high molecular weight and the way it is processed into fibres combine to give polypropylene fibres very useful properties as explained below.

- There is a sterically regular atomic arrangement in the polymer molecule and high crystallinity. Due to regular structure, it is known as isotactic polypropylene.
- Chemical inertness makes the fibres resistant to most chemicals. Any chemical that will not attack the concrete constituents will have no effect on the fibre either.
- The hydrophobic surface not being wet by cement paste helps to prevent chopped fibres from balling effect during mixing like other fibres.
- The orientation leaves the film weak in the lateral direction which facilitates fibrillations. The cement matrix can therefore penetrate in the mesh structure between the individual fibrils and create a mechanical bond between matrix and fibre.

The fibres are manufactured either by the pulling wire procedure with circular cross section or by extruding the plastic film with rectangular cross-section. They appear either as fibrillated bundles, mono filament or microfilaments. The fibrillated polypropylene fibres are formed by expansion of a plastic film, which is separated into strips and then slit. The fibre bundles are cut into specified lengths and fibrillated. In monofilament fibres, the addition of buttons at the ends of the fibre increases the pull out load. Further, the maximum load and stress transfer could also be achieved by twisting fibres.

Fig.1.10. Polypropylene fibres before mixing with the concrete materials

CHAPTER 2

LITERARY REVIEW

2.1 General

Fibre reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibres. Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes discontinuous fibres is to bridge across the cracks that develop provides some post cracking "ductility". If the fibres are sufficiently strong, sufficiently bonded to material, and permit the FRC to carry significant stresses over a relatively large strain capacity in the post cracking stage. There are, of course, other (and probably cheaper) ways of increasing the strength of concrete. When the fibre reinforcement is in the form of short discrete fibres, they act effectively as rigid inclusions in the concrete matrix. Physically, they have thus the same order of magnitude as aggregate inclusions; steel fibre reinforcement cannot therefore be regarded as a direct replacement of longitudinal reinforcement in reinforced and pre-stressed structural members. However, because of the inherent material properties of fibre concrete, the presence of fibres in the body of the concrete or the provision of a tensile skin of fibre concrete can be expected to improve the resistance of conventionally reinforced structural members to cracking, deflection and other serviceability conditions. The fibre reinforcement may be used in the form of three – dimensionally randomly distributed fibres throughout the structural member when the added advantages of the fibre to shear resistance and crack control can be further utilised. On the other hand, the fibre concrete may also be used as a tensile skin to cover the steel reinforcement when a more efficient two – dimensional orientation of the fibres could be obtained. The conclusions about various properties of FRC from the various studies conducted can be summarised as follows:

2.1.1 Compressive strength

Compressive strength of concrete is one of the most important properties of concrete. The compressive strength varies as a function of both cement paste and fibres.

Anbuvelan et al. (2007) carried out tests for strength Prediction of Polypropylene Fibre Reinforced Concrete. Test results showed that the addition of polypropylene fibres to plain concrete increases its compressive strength from 4% to 17%.

Kumar et al. (2014) carried out experimental investigations on M15, M20 and M25 grade fly ash concrete reinforced with 0%, 0.5% and 1% polypropylene fibres. The compressive strength also increased with increase in fibre content up to 1% for all the three grades of concrete.

Priti A. Patel et al. (2012) found that the compressive, split tensile and flexural strength improved on addition of 1.5 % of polypropylene fibre in the concrete.

Nguyen et al. (2012) conducted study on the use of steel fibres in Reinforced concrete. They concluded that the compressive strength increased by 25% and the fibres also substantially increased the post cracking ductility of the material.

2.1.2 Split Tensile Strength

When tensile stress is transferred to fibres, the micro cracks are arrested and thus improve the split tensile strength of concrete.

Gencel et al. (2011) conducted the split tensile strength using fibres up to 9 kg/m3. It is found that the split tensile strength increased with increasing fibre content Fibres tend to bridge the micro cracks and hamper the propagation of cracks. When tensile stress is transferred to fibres, the micro cracks are arrested and thus improve the split tensile strength of concrete.

Murahari et al. (2013) from their experimental investigations observed that there is not much significant interference of fibres on the split tensile strength. The split tensile strength gained more strength at early age of 28 days compared to 56 days.

Ahsana et al. (2013) carried out tests for M20 grade concrete using hooked steel fibres and crimped steel fibres. Test results showed that the addition of hooked steel fibres to plain concrete increases its compressive strength by 33% while crimped steel fibres increased the strength by 42%.

Nguyen et al. (2012) conducted study on the use of steel fibres in Reinforced concrete. They concluded Fibres aligned in the direction of the tensile stress may bring about very large increases in direct tensile strength, as high as 133% for 5% of smooth, straight steel fibres. However, for more or less randomly distributed fibres, the increase in strength is much smaller, ranging from as little as no increase in some instances to perhaps 60%.

2.1.3 Flexural Strength

There is marginal increase in flexural strength at first crack as fibre content increased from 0% to 1.0% .Under three points loading in accordance with ASTM C78. It is observed that the flexural strength increased with content up to 1.0% and gained more strength at 28 days when compared to 56 days.

Gencel et al. (2011) reported that the flexural strength increases with addition of fibre content.

Kumar et al. (2014) studied the with M15, M20 and M25 grade concrete with 0%, 0.5 % and 1% fibres for flexure and shear behaviour of deep beams and it is reported that there is marginal increase in flexural strength at first crack as fibre content increased from 0% to 1.0%.

Murahari et al. (2013) tested 500 x 100 x 100 mm specimens under three point loading in accordance with ASTM C78. It is observed that the flexural strength increased with content up to 0.3% and gained more strength at 28 days when compared to 56 days.

Ahsana et al. (2013) carried out tests for M20 and M30 grade concrete using hooked steel fibres and crimped steel fibres. Test results showed that the addition of hooked steel fibres to plain concrete increases its compressive strength by 39% while crimped steel fibres increased the strength by 45%.

Mohod et al. (2012) carried out experimental investigations on M30 grade concrete using hooked steel fibres. They concluded that the max. Flexural strength was obtained at 0.75%.

Nguyen et al. (2012) conducted study on the use of steel fibres in Reinforced concrete. They concluded at 1% steel fibre composition, the flexural strength of the beam increased by 42%.

2.2 The inferences made from various studies conclude that:

1. It is observed that the workability of fibre reinforced concrete gets reduced as the percentage of fibres content increases.
2. “Addition of polypropylene fibres to plain concrete increases its compressive strength from 4% to 17%.
3. The split tensile strength increased with increasing fibre content Fibres tend to bridge the micro cracks and hamper the propagation of cracks.
4. Fibres aligned in the direction of the tensile stress may bring about very large increases in direct tensile strength.
5. There is marginal increase in flexural strength at first crack as fibre content increased from 0% to 1.0%.
6. The flexural strength increased with content up to 0.3% and gained more strength at 28 days when compared to 56 days.
7. The flexural strength of concrete goes on increasing with the increase in fibre content up to the optimum value. The optimum value for flexural strength of steel fibre concrete was found to be 0.75%.
8. While testing the specimens, the plain cement concrete specimens have shown a typical cracks propagation pattern which leaded into splitting of beam in two piece geometry. But due to addition of steel fibres in concrete cracks gets ceased which results into ductile behaviour of SFRC.

CHAPTER 3

EXPERIMENTAL PROGRAMME

3.1 General

In order to study the suitability of polypropylene fibre in concrete, tests were conducted on M60 grade concrete. Mix design was done as per IS: 10262 - 2009. Following tests were conducted for this study.

Table 3.1: Tests on aggregates, cement and concrete

Sl. No.	Tests to be conducted
1	Specific gravity of OPC
2	Specific gravity and Water absorption of Coarse Aggregate
3	Specific gravity and Water absorption of Fine Aggregate
4	Fineness modulus of Fine Aggregate
5	Nominal size of Coarse aggregate
6	Compressive Strength Test
7	Split Tensile Test
8	Flexural Strength Test

The materials required were Ordinary Portland cement grade 53, coarse aggregate, fine aggregates and polypropylene fibre. The concrete was tested in four batches consisting of the following:

1. Plain cement concrete of M60 grade having cement: fine aggregate: coarse aggregate ratio of 1: 1.1.35:2.19:0.29
2. Polypropylene fibre reinforced concrete of M60 grade for fibre content of 0.5%, 1.0% and 1.5% of cement content in the mix.

3.2 Specification of Materials

Checking of materials is an essential part of civil engineering as the life of structure is dependent on the quality of material used. IS: 10262 – 2009 deals with Mixed Design of Concrete and thus it depend on different properties of cement and aggregates. The properties that the Concrete Mix Design requires are specific gravity, water absorption, fineness modulus and workability.

The main objective of this project is to compare the changes in strength properties in plain cement concrete and fibre reinforced concrete. The most important property of concrete is probably strength, although many other characteristics like durability may be equally important. On the other hand, concrete strength is an elusive property. Even if all the many factors that are known to affect the strength – the properties and inherent variability in the concrete making materials, proportions, air content, mixing, temperature and others – are absolutely constant, the may be a wide dispersion in the numerical values of the measured strength depending on how well the ingredients are mixed.

3.3 Materials

3.3.1 Ordinary Portland cement (OPC)

Portland Pozzolana cement (PPC) is manufactured by the inter-grinding of OPC clinker with 10 to 25 per cent of pozzolanic material (as per the latest amendment, it is 15 to 35%). A pozzolanic material is essentially a siliceous or aluminous material which while in itself possessing no cementitious properties, which will, in finely divided form and in the presence of water, react with calcium hydroxide, liberated in the hydration process, at ordinary temperature, to form compounds possessing cementitious properties.

The pozzolanic materials generally used for manufacture of PPC are calcined clay (IS: 1489 (Part II) - 1991) or fly ash (IS: 1489 (Part I) - 1991). Fly ash is a waste material, generated in the thermal power station, when powdered coal is used as fuel. Calcium silicates produce considerable quantities of calcium hydroxide, which is by and large a useless material from the point of view of strength or durability. If such useless mass could be converted into a useful cementitious product, it considerably improves quality of concrete. The use of fly ash performs such a role. The pozzolanic action is shown below: Calcium hydroxide + Pozzolana + water → C – S – H (gel).

Portland pozzolana cement produces less heat of hydration and offers greater resistance to the attack of aggressive waters than ordinary Portland cement. Moreover, it reduces the leaching of calcium hydroxide when used in hydraulic structures. It is particularly useful in marine and hydraulic construction and other mass concrete constructions.

3.3.2 Fine Aggregates

Fine aggregate that will be used is natural sand. Natural sand is available abundantly available in coastal areas and thus widely used all over India. Advantages of natural sand are that the particles are Cubical or rounded with smooth surface texture. Being cubical and rounded and smooth textured it gives good workability. Size less than 4.75 mm is considered as fine aggregates.

3.3.3 Coarse Aggregates

Coarse aggregates available are crushed angular aggregates. The shape of aggregates is an important characteristic since it affects the workability of concrete. Crushed angular aggregates possess well defined edges. Angular aggregates exhibit a better interlocking effect in concrete, which property makes it superior in concrete used for roads and pavements. The total surface area of rough textured angular aggregate is more than smooth rounded aggregate for the given volume. By having greater surface area, the angular aggregate may show higher bond strength than rounded aggregates.

3.3.4 "Polypropylene Fibre

Polypropylene is a100% synthetic fibre which is transformed from 85% propylene. The monomer of polypropylene is propylene. Polypropylene is a by-product of petroleum.

Polypropylene (PP) is a thermoplastic. It is a linear structure based on the monomer CnH2n.

It is manufactured from propylene gas in presence of a catalyst such as titanium chloride. Beside PP is a by-product of oil refining processes.

Most polypropylene used is highly crystalline and geometrically regular (i.e. isotactic) opposite to amorphous thermoplastics, such as polystyrene, PVC, polyamide, etc., which radicals are placed randomly (i.e. atactic).

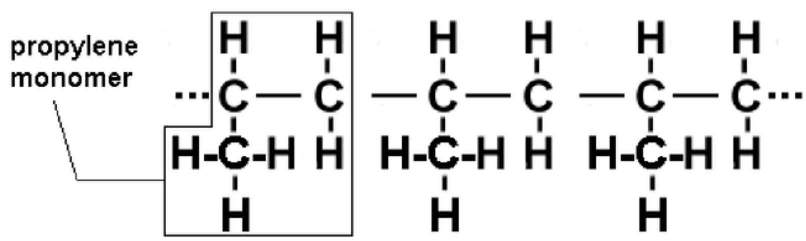

Fig.3.3.4 Chemical Bond Polypropylene Polymers

3.3.5 Properties of Polypropylene fibre

Some of the important properties of polypropylene fibre are:

1) Thermal Conductivity

Lowest thermal conductivity of any natural or synthetic fibre is 6.0 compared to 7.3 for wool, 11.2 for viscose and 17.5 for cotton.

2) Anti-Static Behaviour

Practical experience shows that polypropylene does not exhibit a static behaviour in most normal circumstance and if a problem does occur it can easily be controlled by the use of normal textile anti-static treatments during processing. Anti-static agents can also be incorporated in the polymer to reduce static build up.

3) Resistant to Bacteria and Micro-organisms

Like other synthetic fibres – nylon, acrylic and polyester – polypropylene fibres are not attacked by bacteria or micro-organisms; they are also moth-proof and rot-proof.

4) Environmental Effect

It is recyclable, ecologically friendly and incinerates to trace ash with no hazardous volatiles.

5) Effect of Heat

The melting point of polypropylene is about 165°C and while it does not have a true softening point temperature, the maximum processing temperature of the fibre is approximately 140°C. Prolonged exposure to elevated temperatures will cause degradation of the fibre, but anti-oxidants are incorporated in polypropylene fibres to protect them during processing and at normal service temperatures.

The shrinkage of polypropylene fibre is controlled by its manufacturing conditions. At textile processing temperatures, which do not normally exceed 130°C., the shrinkage varies between 2.5% to 5%, but figures as high as 30% can be obtained, or by conditioning the fibre or yarn, as low as 0.5%.

6) Effect of Extreme Cold

It remains flexible at temperatures in the cold region as low as -55°C.

7) Flammability

Polypropylene fibre burns and presents much the same risks as most other man-made textile fibres. It is difficult to ignite, and is defined as combustible but not highly inflammable. It can, however, be rendered flame-retardant by the incorporation of additives.

8) Water Absorption

The water absorption of polypropylene fibre is about 0.3% after 24 hours immersion in water, and thus its regain – the amount of water absorbed in a humid atmosphere – is virtually negligible.

9) Resistant to Staining

Because of their extremely low water absorption, polypropylene fibres resist water-borne stains better than any other fibres. And since the fibre does not accumulate static though friction during use, it does not attract as much dirt or dust as other man-made fibres.

10) Effect of Acids

Polypropylene fibres are excellent resistance to most acids except chlorosulphonic and concentrated sulfuric acid.

3.3.6 Specifications of Polypropylene fibre used in testing

The polypropylene fibre used in concrete mix is from Recron© 3S, the New Generation "Secondary reinforcement" for Construction Industry.

"Recron 3S has a wide number of applications in the construction industry."

- **Concrete:** floor, slab, beams, piles, retaining walls, intel, road, bridges, airport runways etc.

- **Advantages of using Recron© 3S:**
  - Improves homogeneity of the concrete by reducing segregation of aggregates.
  - Reduces shrinkage cracks/micro cracks.
  - Increase impact and shatter resistance by 100%.
  - Increases ductility, compressive, flexural and tensile strength.
  - Reduces water permeability which helps prevent correction of primary steel.
  - Increases energy absorption capability of concrete.

Table 3.3.6 specifications of polypropylene fibre used

Sl. No	Descriptions	value
1	Cut length or chop length	12 mm
2	diameter	34 µ
3	density	0.910 g/cm²
4	Melting Point	>250 ºC
5	Colour	white
6	Tensile strength	300-400 N/mm²
7	Chemical resistance	excellent-especially in alkaline condition
8	Dosages	Concrete use 12mm@900 gms/cubic meter

3.4 Tests on Cement and Aggregates for Mix Design

Following tests were conducted in order to check the feasibility of the materials required for mix design.

1. Specific gravity of PPC using Le Chatiliers' Flask
2. Specific gravity and water absorption of Coarse Aggregate
3. Specific gravity and water absorption of Fine Aggregate
4. Fineness modulus of fine aggregate

5. Nominal size of coarse aggregate

3.4.1. Specific gravity of OPC using Le Chatiliers' Flask

Specific gravity of cement is found out by using Le Chatelier's flask. The procedure for the test is done as given below as per IS: 4031 (Part XI).

Test Procedure

I. Weigh a clean and dry Le Chatelier Flask or Specific Gravity Bottle with its stopper (W l).
II. Place a sample of cement up to half of the flask (about 50 gm) and weight with its stopper (W*2*).
III. Add kerosene (polar liquid) to cement in flask till it is about half full. Mix thoroughly with glass rod to remove entrapped air. Continue stirring and add more kerosene till it is flush with the graduated mark. Dry the outside and weigh (W*3*).
IV. Entrapped air may be removed by vacuum pump, if available. Empty the flask, clean it refills with clean kerosene flush with the graduated mark wipe dry the outside and weigh (W*4*). Specific gravity of given kerosene is 0.79.

Result:

Specific gravity of OPC was found out to be 3.15 which conform to IS: 1489 (Part 1). Detailed calculations and data are given in Annexure I.

3.4.2. Specific Gravity and Water Absorption of Fine Aggregate

This test can be conducted using pycnometer or density bottle. I conducted pycnometer to find specific gravity and water absorption.

Test Procedure

Take an empty pycnometer bottle and weigh it (W1). Add fine aggregate passing through 4.75mm sieve about 1/3 of bottle and weigh it (W2). Now add water till its full and shake it till there is no entrapped air inside, put its cone shaped top and fill all the way till the water reaches the cone cap and weigh it (W3). Remove the sample and place it in a container and draw out water and filer the water and place the sample in oven for 24 hrs. Then fill the pycnometer with water and weigh it (W4).

Result:

Specific gravity of fine aggregate was found to be **2.5** and water absorption was **0.79%** According to IS 2386 (Part III), the range of specific gravity suitable for Concrete mix is 2.5 to 3. Our result is within that limit so it can be used for mix Design.

Detailed calculations and data are given in Annexure 1.

3.4.3. Specific Gravity and water absorption of Coarse Aggregate

This test is conducted by following the procedure mentioned in IS: 2386 (Part III)

Test procedure:

The sample shall be thoroughly washed to remove finer particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22°C and 32°C with a cover of at least 5 cm of water above the top of the basket. Immediately after immersion the entrapped air shall be removed from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at the rate of about one drop per second.

The basket and aggregate shall remain completely immersed during the operation and for a period of 24 ± l/2 hours afterwards. The basket and the sample shall then be jolted and weighed in water at a temperature of 22 to 32oC. (Weight A). The basket and the aggregate shall then be removed from the water and allowed to drain for a few minutes, after which the, aggregate shall be gently emptied from the basket on to one of the dry clothes, and the empty basket shall be returned and weighed in water. The aggregate placed on the dry cloth shall be gently surface dried with the cloth. The aggregate shall then be weighed (weight B). The aggregate shall then be placed in the oven in the shallow tray, at a temperature of 100 to 110°C and maintained at this temperature for 24 ± l/2 hours. It shall then be removed from the oven, cooled in the airtight container and weighed (weight C).

Result:

Specific gravity of coarse aggregate was found out to be **2.78** while its water absorption was **2.77%.**

Detailed calculations and data are given in Annexure 1.

3.4.4. Fineness Modulus of Fine Aggregates

Fineness modulus is a ready index of coarseness or fineness of the material. Fineness modulus is an empirical factor obtained by adding the cumulative percentages of aggregate retained on each of the standard sieves ranging from 80 mm to 150 micron and dividing this sum by an arbitrary number 100. The larger the figure, the coarser is the material.

Test Procedure:

Sieve analysis is to be carried out in order to determine the fineness modulus of the fine aggregate. Sieves sizes of 4.75 mm, 2.36 mm, 1.18 mm, 600 μm, 300 μm and 150 μm. Take about 1.5 kg of sand and do sieve analysis. Calculate percentage passing for each sieve. Tally the result given in Table 4 of IS 383.

Result:

Fineness modulus of the sample was found out to be **2.74**. From Table 4 of IS: 383 (1970), the sample conforms to Zone II.

Detailed calculations and data are given in Annexure 1.

3.4.5. Nominal size of coarse aggregate

According to size coarse aggregate is described as graded aggregate of its nominal size i.e. 40 mm, 20 mm, 16 mm and 12.5 mm etc. for example a graded aggregate of nominal size 20 mm means an aggregate most of which passes 20 mm IS sieve. Nominal size is used to decide the water content in the concrete mix. Hence this test has to be carried out.

Test procedure:

Sieve analysis has to be done for this test as well. Sieve sizes of 80 mm,63 mm,40 mm,20 mm,16 mm,12.5 mm,10 mm, 4.75 mm and 2.36 mm are used. Once the percentage passing has been calculate, the results are tallied with table 2 of IS: 383 (1970).

Result:

The nominal size of the coarse aggregate sample is **20 mm.**

Detailed calculations and data are given in Annexure 1.

3.5 Test Results

Following results were obtained based on above tests.

Table 3.5.1: Tests Results

Sl. No.	Tests	results
1	Specific gravity of OPC	3.15
2	Specific gravity of Fine aggregates	2.50
3	Specific gravity of Coarse aggregates	2.78
4	Fineness modulus of fine aggregate	2.48
5	Nominal size of coarse aggregate	20 mm
6	Water absorption of Fine aggregate	0.79 %
7	Water absorption of Coarse aggregate	2.77 %

3.5.1. Discussion on test results

The results are satisfactory and the materials are suitable for use in mix design. Specific gravity of OPC is 3.15 which conform to IS: 1489 (Part I). Specific gravity of coarse and fine aggregate is with the limit specified in IS: 2386 (Part III) which is 2.5 – 3. Similarly water absorption is below the required 5% limit. Hence the materials are suitable for use in mix design."

25 Sieve analyses have to be done for this test as well. Sieve sizes of 80 mm, 63 mm, 40 mm, 20 mm, 16 mm, 12.5 mm, 10 mm, 4.75 mm and 2.36 mm are used. Once the percentage passing has been calculated, the results are tallied with Table 2 of IS: 383.

(Table AI.5a).

3.6 M60 Mix design

Design mix ratio of cement, sand, coarse aggregate and water**: 1: 1.11: 2.02:0.3**

Detailed design procedure is given in Annexure 2.

3.7 Experimental Investigation

3.7.1. Details of specimens

For all tests, M60 grade concrete was used. M60 grade is of design mix of **1: 1.11: 2.02:0.3** and water cement ratio of 0.3 as mentioned in section 3.6.

The objective of our study is to find out the changes in strength properties of fibre reinforced concrete in comparison to plain cement concrete. Hence evaluations of compressive strength, split tensile strength and flexural strength is done as per standards.

3.7.2. Casting and curing of specimens

Concrete was mixed in a tilting type drum mixer and cast as per IS: 516 (1959). Standard moulds of cube 150 mm x 150 mm x 150mm, cylinder 100 mm diameter and 200 mm height and beams of 100 mm x 100 mm x 500 mm was used. Concrete was poured and compacted using tamping rod in three layers. After 24 hours the mould was disassembled and the concrete was kept in normal curing tank for 7 days curing,14 days curing and for the 28 days curing, samples were placed in normal curing tank. In normal curing, a sample is kept in water at temperature of 27±2°C for required days until the specimens are taken out for testing 2 hours before testing. After that tests were conducted upon surface drying.

Figure 3.7 Curing of Specimens in Curing Tank

3.8 Details of Testing

The constituent materials of concrete are cement, fine aggregates, coarse aggregates, were tested for suitability of their use as per relevant Indian Standard codes. Concrete of M20 was designed. The three strength tests to be carried out were compressive strength test, split tensile test and flexural strength test. The specimen details are tabulated below.

Table no. 3.8 details of specimen used

Sl. No	Test descriptions	Specimen dimension (mm)
1	Compressive strength test	100x100x100
2	Split tensile strength test	100φx200
3	Flexural strength test	100x100x500

Figure 3.8 Cubes, Beams and Cylinder specimens used in testing

3.8.1 COMPRESSION TEST

This test was conducted as per IS 516-1959. The cubes of standard size 100x100x100mm were used to find the compressive strength of concrete. Specimens were placed on the bearing surface of CTM/UTM, without eccentricity and a uniform rate of loading of 550kg/cm2 per minute was applied till the failure of cube. The maximum load was noted and the compressive strength was calculated.

Cube compressive strength (fck) in $MPa = P/A$

Where;

P = Maximum Cube compression load

A = Area of cube on which load is applied (150x150x150)

Fig. 3.8.1 compressive testing of cubes in UTM

3.8.2 SPLIT TENSILE STRENGTH

Fibres aligned in the direction of the tensile stress may bring about very large increases in direct tensile strength, as high as 133% for 5% of smooth, straight fibres. However, for more or less randomly distributed fibres, the increase in strength is much smaller, ranging from as little as no increase in some cases to 60%.with many investigations indicating intermediate values. Thus, adding fibres merely to increase the direct tensile strength is probably not worthwhile. However, as in flexural, fibres do lead to major increases in the post-cracking behaviour and flexural toughness of the composites.

Split tensile strength is calculated using the formula:

$$\tau = \frac{2P}{\pi D l}$$

Where;

P=maximum split load applied on specimen

D= diameter of the cylinder specimen

l= length of specimen in mm

Fig. 3.8.2 testing cylinders for split tensile strength and failed samples

3.8.3. FLEXURAL TEST

Fibres are generally found to have aggregate much greater effect on the flexural strength than on either the compressive or tensile strength, with increases of more than 100% having been reported. The increases in flexural strength are particularly sensitive, not only to the fibre volume, but also to the aspect ratio of the fibres, with higher aspect ratio leading to larger strength increases.

The modulus of rupture is calculated using the formula:

$$\sigma = Pl/bd2$$

Where:

P =load in N applied to the specimen.

l=length of span in mm

b=measured width in mm

d =measured depth in m

Fig.3.8.3 testing for flexural strength of beams and failed specimen

CHAPTER 4

ANALYSIS OF DATA & DISCUSSION OF RESULTS

4.1 General

The main objective of the present study was to study the mechanical properties of polypropylene fibre reinforced concrete in which a systematic series of experiments were conducted. I performed three main tests which are cubes for compressive strength test, cylinders for split tensile strength and beams for the flexural strength of concrete in the Concrete Laboratory of Civil Engineering Department of Jaypee University of Information and Technology. For durability and resistance against the chemical attacks, I performed acid and alkali test. The results are analysed and discussed below.

4.2 Properties of Plain Concrete

The mechanical properties of M60 plain concrete like compressive strength, split tensile strength and flexural strength were observed by test experiments on cube, cylinder and beam specimens for 7days 14 days and 28 days.

The experiment results show that for the concrete Mix of M60 the average compressive strength was found to be 42.5MPa, 58.1 MPa and 63.5 MPa for 7 days, 14 days and 28 days respectively.

The average split tensile strength was found to be 5.8 MPa, 7.2 MPa and 7.6 MPa for 7 days, 14 days and 28 days respectively.

The average flexural strength was found to be 4.6 MPa, 5.8 MPa and 6.4 MPa for 7 days, 14 days and 28 days respectively.

The detailed results are shown in Annexure III.

4.3 Properties of Fibre Reinforced Concrete

I. Compressive strength

Concrete is the material that has the high compressive strength so it is most important properties of concrete and influences many other desirable properties like hardened concrete. Cubes were tested on Universal Testing Machine (UTM), for 7 days 14 days and 28 days strength.

The addition of Polypropylene fibre to influence the strength of concrete at 0.5%, 1.0% and 1.5% of fibre weight to the weight of concrete used in the concrete mix and the results are tabulated in the tables shown in Annexure III.

It is observed that the maximum average increase in 7 days compressive strength of M60 concrete is 19.3% w.r.t plain concrete at 0.5% fibre content. Whereas for 1.0% and 1.5% the averages increase in 7 days compressive strength was found to be 17.8% and 15.5% respectively. It was observed that the maximum average increase in 14 days is

18.8% w.r.t plain concrete at 0.5% fibre content. Similarly for 1.0% and 1.5% fibre content was found to be 15.6% and 14.3% respectively. For 28 days compressive strength the average maximum increase in strength is 17.6% foe M60 at 0.5%. Similarly for 1.0% and 1.5% fibre content the average increase was 14.3% and 11.7% respectively.

The average percentage increase in the compressive strength for various fibre contents is plotted in figure 4.3I.

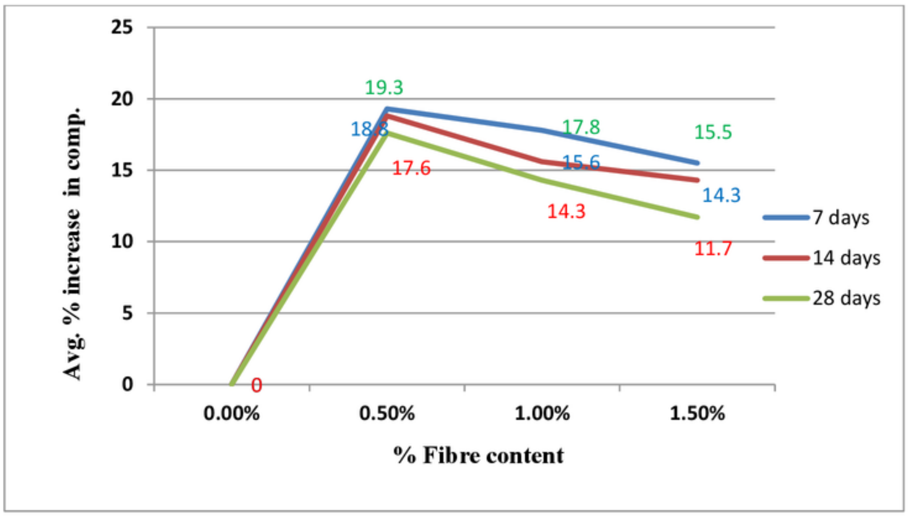

Figure 4.3I Average % increase in compressive strength Vs % Fibre content

II. Split tensile strength

Similarly for split tensile test, cylinders were cast and these were tested on CTM, for 28 days and the values are presented in the tables in annexure III.

For polypropylene fibre reinforced concrete of M60 grade, the maximum average increase in 7 days split tensile strength was found to be 48.1% at a fibre content of 0.50%. At the fibre contents of 1.0% and 1.50% the percentage increase was found to be 47.6% and 45.9% respectively. It is observed that 7 days test results have the maximum average increase in strength.

For 14 days strength the average increase was found to be 45.3%, 44.7% and 40.5% for 0.5%, 1.0% and 1.5% fibre content respectively.

For 28 days strength the average increase in strength w.r.t plain concrete was found to be 43.7%, 37.8% and 36.9% for 0.5%, 1.0% and 1.5% fibre content respectively.

The average split tensile strength increase for various fibre contents is plotted in figure 4.3II.

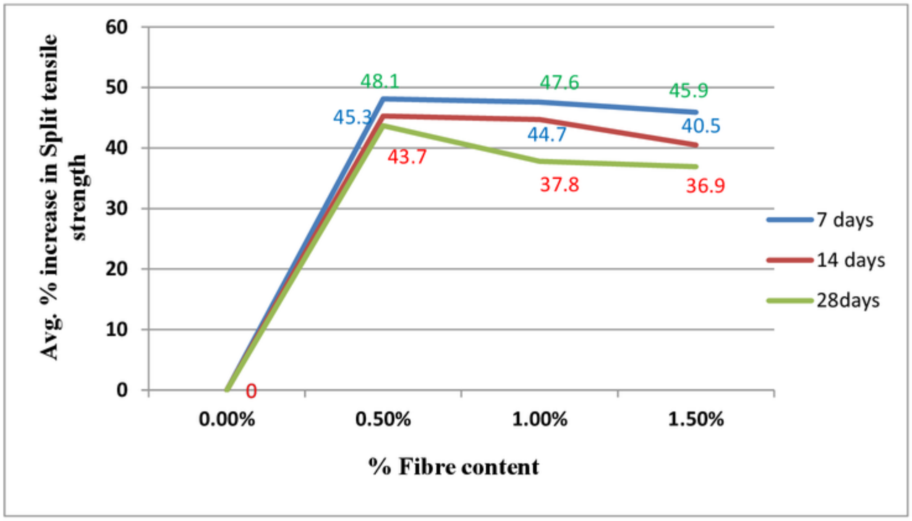

Figure 4.3II Average % increase in Split tensile strength Vs % Fibre content

III. Flexural Strength

For the flexural strength investigation, beams were casted and were tested in Universal Testing Machine (UTM), for 28 days and the values are presented in the tables in annexure III.

For polypropylene fibre reinforced concrete of M60 grade, the maximum average increase in 28 days flexural strength was found to be 33.5% at a fibre content of 0.50%. At the fibre contents of 1.0% and 1.50% the percentage increase was found to be 31.11% and 28.9% respectively.

For 14 days strength the average increase was found to be 36.6%, 35.2% and 34.7% for 0.5%, 1.0% and 1.5% fibre content respectively.

For 7 days strength the average increase in strength w.r.t plain concrete was found to be 39.5%, 38.6% and 35.1% for 0.5%, 1.0% and 1.5% fibre content respectively. The 28 days average split tensile strength increase for various fibre contents is plotted in figure 4.3III.

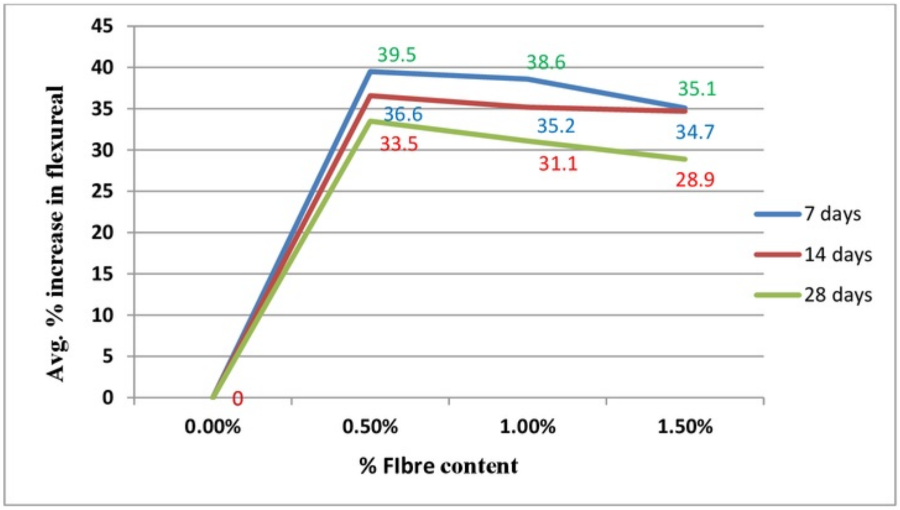

Figure 4.3III Average % increase in Flexural strength Vs % Fibre content

4.4 Acid and alkali test on the PPFR Concrete.

Acid and alkali test were conducted in Environmental Laboratory Civil Department and the details and procedure are given in annexure III.

The acid test result: the percentage weight loss is **3.5%.**
The alkali test result: the percentage weight loss is **0.3%.**

Figure 4.4 Cube after the Alkali and Acid respectively

4.5 Comparisons with the other studies

4.5.1 Polypropylene fibre reinforced concrete

In order to compare the effects of Polypropylene fibre on the mechanical properties of concrete, the results of Er. Darole J. S. *et al. (2013)* have been compiled below.

According to the study conducted by *Saeed et al.* the addition of polypropylene fibres at low values (0.20%-0.50%) actually increased the 28 days compressive strength but when the volumes get higher, the compressive strength decreased from original by 3 to 5%. The tensile strength increased about 45%~75% % up to 0.50% after which it decreased. There was about 40% increase in flexure strength by addition of 0.50% fibres in concrete after which strength started reducing with further increment in fibre ratios. The shear capacity of concrete increased when fibres were added. There was a remarkable increase in load carrying capacity up to first crack appeared. The shrinkage cracking was reduced by 83 to 85% by addition of fibres up to 0.35% and 0.50 %. For higher percentage of fibre content many papers observe decreases in strengths.

In our study on the effects of PP fibre on the mechanical properties of concrete it was observed that the maximum average increase in 7 days compressive strength of M60 concrete is 19.3% w.r.t. plain concrete at 0.5% fibre content. It was observed that the maximum average increase in 28 days compressive strength of M60 concrete is 17.6% w.r.t. plain concrete at 0.5% fibre content. A decrease of 1.7% in compressive strength was observed at the fibre content of 0.50. It can be seen that the average increase in 7 days split tensile strength of M60 concrete is 48.1% at 0.5% fibre content and average increase in 28 days split tensile strength was found to be 43.7% and decrease of 4.4%. It can be seen that the average increase in 7 days flexural strength of M60 concrete is 39.5% at 0.5% fibre content and for 28 days flexural strength was found to be 33.5% and decrease of 6% in strength. Thus, it can be seen that the previous studies support our results and have almost same results for the tests that we conducted.

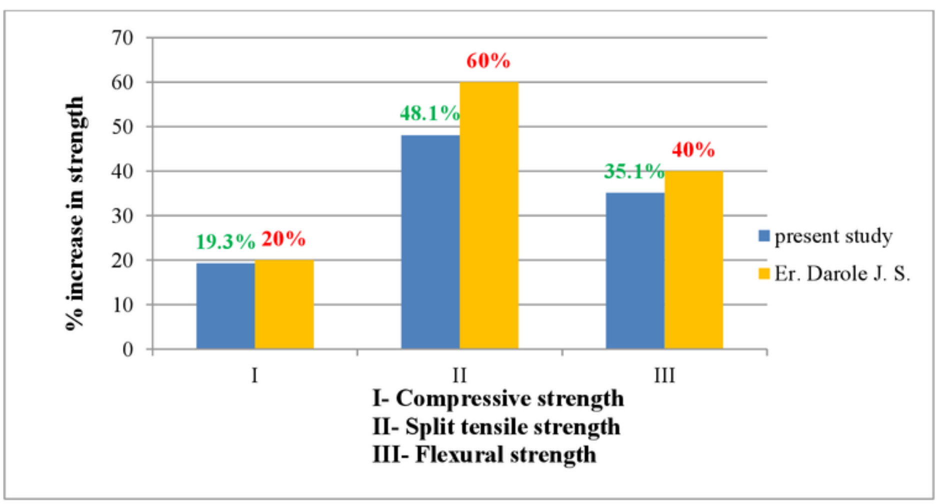

Figure 4.5.1 Comparison with other studies for PPFRC

4.5.2 Comparison with my previous study of M20 concrete with Polypropylene Fibres

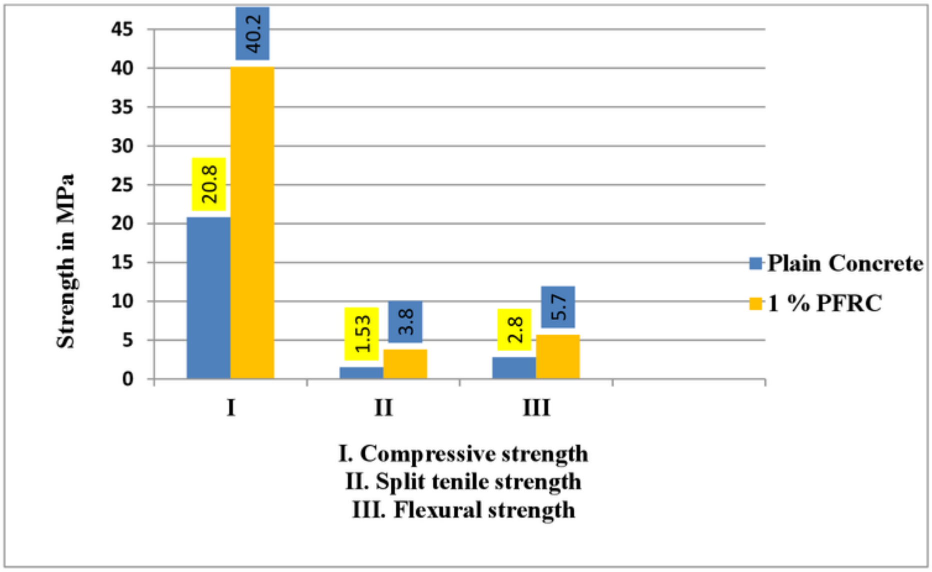

Figure 4.5.2a Comparison of 28 days strength of Plain Concrete and 1 % PFRC of M20 grade

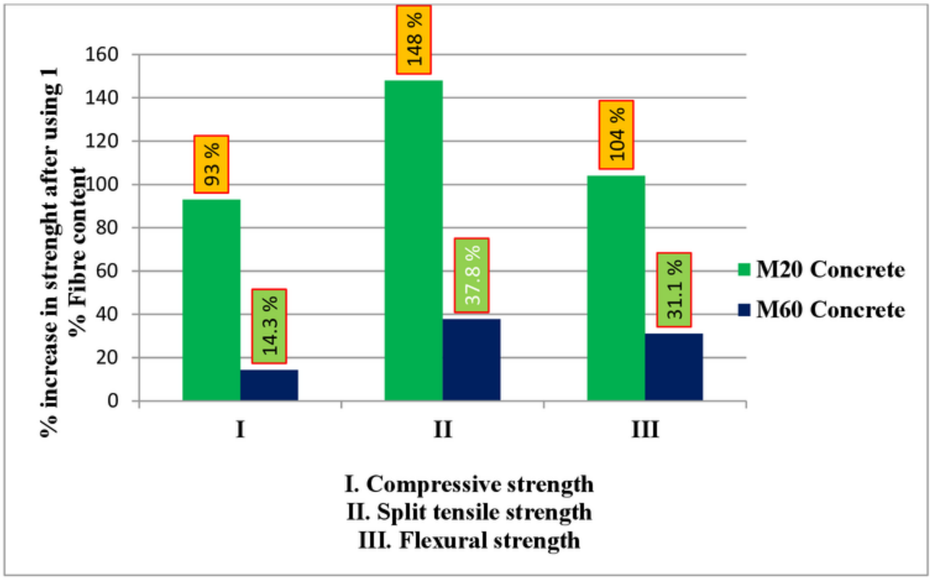

Figure 4.5.2b Comparison based on the average % increase of 1% fibre content of M20 and M60 PFRC

There are very high percentage differences in the average increase of strength with same fibre content percentage in different Mix designs.

For Compressive strength improvement of plain concrete, the M20 Mix grade has 78.7 % more increased strength than M60 Mix grade.

Similarly for Split tensile strength the concrete gained more strength in M20 Mix grade then M60 Grade, by 110.2 % more strength improvements.

And for Flexural strength M20 Mix Grade gained 72.9 % more strength than M60 grade concrete.

Therefore, the 28 days strength of M20 Mix grade with same Polypropylene Fibre content as M60 Mix grade has more strength gained. So we can conclude that the polypropylene fibre when reinforced with lower grade of concrete Mix gives more increased strength than high strength concrete.

CHAPTER 5

CONCLUSIONS

Conclusion

At present there are different kind of fibres are available and are widely used in concrete to improve its strength, durability of the matrices and other physical pro-mechanical properties of concrete. Fibres added in dosages of 0.5% and above by volume of concrete, enhance primarily the ductility of concrete, enabling it to undergo large deformations at failure. The compressive strength and first cracking tensile strength of concrete are not affected by the presence of fibres. However, the load carrying capacity in flexure is increased, however the percentage increase in the strength of the concrete with comparison with plain concrete decreases gradually as we use increase the fibre content from 0.5% to 1.5%.

In the present study the polypropylene fibre are used with high strength concrete M60 grade. After conducting testing and experiments the following conclusions were drawn:

1. The addition of polypropylene fibre to the high strength concrete actually increases the general strength of the concrete mix.
2. There is more increase in the early days of the concrete i.e., 7 days strength improvement is better than 28 days strength of the M60 concrete.
3. For the compressive strength there is improvement of around 15.5% of strength compared to the plain concrete. There is about 1.5% decreases in percentage of improvement from 7 days to 14 days and 28 days respectively.
4. The split tensile strength increased by around 42.5% and it dropping gradually by 1% and 2.5% for 7 days strength respectively and also a decrease in the percent improvement of 5% from 7 days strength to 28 days strength.
5. The flexural strength of M60 grade concrete increases around 34.2% and a gradual drop by 1% and 3.5% respectively for fibre content 1% and 1.5%. The percentage improvement decrement is around 3% form 7 days strength to 28 days strength.
6. There is definitely a large increase in the strength of the M60 grade concrete however it more suitable with low strength concrete, since the percentage improvement for low strength concrete is much higher.
7. The acid and alkali test for percentage weight loss of the PPFR concrete was 3.5% and 0.3% respectively after 30 days in the respective solution of 5% sulphuric acid and 5% sodium sulphate solutions.
8. The maximum or optimum fibre content in the concrete should not exceed 0.5% fibre content by weight because the maximum improvement is at 0.5% fibre content and is decreasing gradually as the fibre content increases.
9. 28 days strength of M20 Mix grade with same Polypropylene Fibre content as M60 Mix grade has more strength gained. So we can conclude that the polypropylene fibre when reinforced with lower grade of concrete Mix gives more increased strength than high strength concrete.

CHAPTER 6

ANNEXURES

Annexure I
Preliminary Test Results and Calculations

AI.1 Specific Gravity of OPC

Table: AI.1 Data for Specific Gravity of OPC

Sl. No.	Details Result	Designation	weight (gm)
1	Weight of empty density bottle	W1	15.8
2	Weight of density bottle filled full with water	W2	57.8
3	Weight of density bottle filled full with oil	W3	55.5
4	Wight of density bottle with oil and cement	W4	90.2
5	Weight of cement in density bottle	W5	50.0

Calculations:

$$Gopc = \frac{W5 \times (W3 - W1)}{(W5 + W3 - W4)(W2 - W1)}$$

$$= \frac{50 \times (55.5 - 15.8)}{(50 + 55.5 - 90.2)(57.8 - 15.8)}$$

G*opc* = 3.15

AI.2 Specific Gravity and Water Absorption of Fine Aggregate

Table AI.2 Data for Specific gravity of fine aggregate

Sl.no	description	Designation.	Wt.in (gm)
1	Wt. of empty bottle	W1	459
2	Wt. of bottle +sand	W2	961
3	Wt. of bottle +sand +water	W3	1559
4	Wt. of bottle +water	W4	1258
5	Wt. of surface dry sand	-	505
6	Wt. of oven dry sand	-	501

Calculations:

$Gs = wt.of\ sand\ /\ wt.of\ equivalent\ water$

$= (W2 - W1)\ /\ ((W4 - W1) - (W3 - W2))$

$= (961 - 459)\ /\ ((1258 - 459) - (1559 - 961))$

Gs =2.50

Water Absorption= $wt.of\ surface\ dry\ by\ wt.of\ oven\ dry$

$= ((505 - 501)\ /\ 501)\ x100$

=0.79 %

AI.3 Specific Gravity and Water Absorption of Coarse Aggregate

Table AI.3 Data for Specific gravity and water absorption of Coarse Aggregate

Sl. No.	Details Results	Dsgn.	weight (gm)
1	Weight of oven dried sample	A	1256
2	Weight of saturated surface dried sample in air	B	1310
3	Weight of saturated surface dried sample in water	C	500

Calculations:

$GCA = B\ /\ (B - C)$

$= 1256/\ (1310x500)$

$GCA = \mathbf{2.78}$

$Water\ Absorption\ = (wt.of\ water\ /wt.of\ coarse\ aggregate)\ x100$

$= (1256 - 1310/500)\ x100$

= 2.77 %

AI.4 Fineness Modulus of Fine Aggregates

Table AI.4a Data for Fineness Modulus

Sieve size in (mm)	Wt. of sand retained in (gm)	Cumulative wt. of sand retained in (gm)	Cumulative percentage in (%)
4.75 mm	10	10	2
2.36 mm	50	60	12
1.18 mm	50	110	22
600 µ	95	205	41
300 µ	185	390	78
150 µ	75	465	93
pan	35	500	
total	**500**		**248**

Calculation:

Fineness Modulus = $\sum(\text{Percentage Passing})/100$

$= 248/100$

= 2.48

Table AI.4b Different Zones of fine aggregate given in Table 4 of IS: 383 (1970)

IS Sieve Designation	Percentage Passing For			
	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10 mm	100	100	100	100
4.74 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	20-70	55-90	75-100	90-100
600 µm	15-34	35-59	60-79	80-100
300 µm	5-20	8-30	12-40	15-50
150 µm	0-10	0-10	0-10	0-15

Fineness modulus of the sample was found out to be 2.48. From Table 4 of IS: 383 (1970), the sample conforms to Zone II.

AI.5 Nominal Size of Coarse Aggregate

Table AI.5a Results for Nominal size of Coarse Aggregates from Table 2 of IS: 383 (1970), the sample confirms to 20 mm nominal size

IS Sieve	Weight Retained (gm)	Cumulative Weight Retained (gm)	Percentage Retained (%)	Percentage Passing (%)
20 mm	233.6	233.6	7.79	92.21
16 mm	1417.2	1650.8	55.02	77.65
6.3 mm	18.9	2996.4	99.87	0.13
4,75 mm	3.2	2996.6	99.88	0.12
Pan	0.5	3000.1	100	0

Table AI.5b Nominal size of coarse aggregate from Table 2 of IS: 383 (1970)

IS Sieve Designation	Percentage Passing for Single-sized Aggregate of Nominal size						Percentage Passing for Graded aggregate of Nominal size			
	63 mm	**40 mm**	**20 mm**	**16 mm**	**12.5 mm**	**10 mm**	**40 mm**	**20 mm**	**16 mm**	**12.5 mm**
80 mm	100	-	-	-	-	-	100	-	-	-
63 mm	85 to 100	100	-	-	-	-	-	-	-	-
40 mm	0 to 30	85 to 100	100	-	-	-	95 to 100	100	-	-
20 mm	0 to 5	0 to 2	85 to 100	100	-	-	30 to 70	95 to 100	100	100
16mm	-	-	-	85 to100	100	-	-	-	90 to 100	-
12.6 mm	-	-	-	-	85 to 100	100	-	-	-	90 to 100
10 mm	0 to 5	0 to 5	0to 2	0 to 30	0 to 45	85 to 100	10 to 35	25 to 55	30 to 70	40 to 85
4.75 mm	-	-	0 to 5	0 to 5	0 to 10	0 to 20	0 to 5	0 to 10	30 to 70	40 to 85
2.36 mm	-	-	-	-	-	0 to 5	-	-	-	-

From Table 2 of IS 383 (1970), the sample conforms to **20 mm** nominal size.

Annexure II

Concrete Mix Design as per IS: 10262 – 2009

AII.1 M60 Mix Design

Table AII.1 Data for calculation of M60 Mix Design

Sl. No	Descriptions	Value
A	**Design stipulation**	
a)	Characteristic comprehensive Strength @ 28 days	60 N/mm²
b)	Type of cement	OPC 53 Grade
c)	Maximum size of aggregate	20 mm
d)	Degree of workability	Collapsible
e)	Degree of quality control	Good
f)	Type of exposure	Severe
g)	Type of aggregate	Crushed angular
h)	Workability	100 mm (slump)
i)	Max. water content	0.35 %
B	**Test data for concrete ingredients**	
j)	Specific gravity of cement	3.15
k)	Specific gravity of fine aggregates (fa)	2.5
l)	Specific gravity of coarse aggregates (ca)	2.78
m)	Water absorption of fine aggregate	0.79 %
n)	Water absorption of coarse aggregate	2.77 %
o)	Min. cement content	450 kg/m3
p)	Chemical admixture	Nil

AII.1.1 Design for M60 Grade Concrete

Step 1: Target mean strength

Target mean strength = Depend upon degree of quality control "good" and considering (std. Dev. As 5 N/mm^2)

$= f'ck = fck + 1.65\, s$

$= 60 + (1.65 \times 5)$

= 68.25 N/mm²

Step 2: selection of Water / Cement Ratio (W/b)

W/b ratio has been selected from the graph from attached as Annexure I i.e., 0 .29 to .345
W/b ratio adopted =.30 (High performance Concrete by P. C. Aitcin, Page No: 235)
W/b ratio adopted = 0.30

Step 3: selection of Water Content

According to IRC: 44 -2008, Table 5, Water Content =186 Kg. Since superplasticizer being to be used, we can reduced the water content between 20% to30%, however we are not using superplasticizer so let the water content = 168 kg.

Water content = 186 kg

Step 4: Cement Content

Cement content = W/b = $168/0.3$

= 560 kg/m³

Step 5: Proportion of Volume of Coarse Aggregate and Fine Aggregate Content

From Table A2.6, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.30 = 0.62.

Sand Content = 38%
= 0.38
Coarse Aggregate:

i) 20 mm =60%
ii) 10mm =40%

Step 6: Mix calculations

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m³

b) Volume of cement $= \frac{\text{mass of cement}}{\text{specific gravity of cement}} \times \frac{1}{1000}$

$= \frac{560}{3.15} \times \frac{1}{1000}$

= 0.177 m³

c) Volume of water $= \frac{\text{mass of water}}{\text{specific gravity of water}} \times \frac{1}{1000}$

$$= \frac{168}{1} \times \frac{1}{1000}$$

= 0.168 m³

d) Volume of all aggregates = [a - (b + c)]
a. = 1- (0.177 + 0.168)
= 0.655 m³

a) Mass of fine aggregate = d x Volume of Fine Aggregate x Specific Gravity of Fine Aggregate x 1000
= 0.655 x 0.38 x 2.5 x 1000
= **623 kg**

b) Mass of coarse aggregate = d x Volume of Coarse Aggregate x Specific Gravity of Coarse Aggregate x 1000
= 0.655 x 0.62 x 2.78 x 1000
= 1130 kg

c) Ratio = Cement: Fine Aggregate: Coarse aggregate: water content
= **560: 623: 1130: 168**
= 1: 1.11: 2.02: 0.3

AII.3 Reference table for Mix Design

Table AII.3a Environmental Exposure Condition (*Table 3 in IS: 456-2000*)

Sl. No	Environment	Exposure Condition
1	Mild	▪ Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal areas
2	Moderate	▪ Concrete surfaces sheltered from severe rain or freezing whilst wet. ▪ Concrete exposed to condensation and rain. ▪ Concrete continuously under water. ▪ Concrete in contact or buried under non aggressive soil/ground water.
3	Severe	▪ Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe Condensation. ▪ Concrete completely immersed in sea water.
4	Very Severe	▪ Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing condition whilst wet.
5	Extreme	▪ Surface members in tidal zone. ▪ Members in direct contact with liquid/solid aggressive chemicals.

Table AII.3b maximum water content per cubic meter of concrete for nominal size of aggregate (*Table 2 in IS: 10262-2009*)

Maximum water content per cubic meter of concrete for nominal maximum size of aggregate		
Sl. No	Nominal max. size of aggregate	Max. Water content
1	10	208
2	20	186
3	40	165

The values given in the table shown above is applicable only for angular coarse aggregate and for a slump value in between 25 to 50mm.
Do the following adjustments if the material used differs from the specified condition.

Table AII.3c Adjustment rules

Type of Material/condition	Adjustment required
For sub angular aggregate	Reduce the selected value by 10 kg
For gravel with crushed stone	Reduce the selected value by 20 kg
For rounded gravel	Reduce the selected value by 25 kg
For every addition of 25 mm slump	Increase the selected value by 3%
If using plasticizer	Decrease the selected value by 5-10%
If using super plasticizer	Decrease the selected value by 20-30%

Note: Aggregates should be used in saturated surface dry condition. While computing the requirement of mixing water, allowance shall be made for the free surface moisture contributed by the fine and coarse aggregates. On the other hand, if the aggregate are completely dry, the amount of mixing water should be increased by an amount equal to moisture likely to be absorbed by the aggregate.

Table AII.3d Volume of coarse aggregate per unit volume of total aggregate for different zones of fine aggregate (Table 3 in IS: 10262 - 2009)

Sl. No	Nominal Max. Size of Aggregate (mm)	Volume of coarse aggregate per unit volume of total aggregate for different zones of fine aggregate			
		Zone IV	Zone III	Zone II	Zone I
1	10	0.50	0.48	0.46	0.44
2	20	0.66	0.64	0.62	0.60
3	40	0.75	0.73	0.71	0.69

Annexure III
Strength Test Results

AIII.1 M60 grade plain concrete mix

Table AIII.1a Compressive strength of plain concrete

Sample	7 days (MPa)	Average	14 days (MPa)	Average	28 days (MPa)	Average
1	41.6	42.5	56.2	58.1	60.6	63.5
2	42.0		58.8		62.6	
3	43.8		59.4		67.2	

Table AIII.1b Split tensile strength of plain concrete

Sample	7 days (MPa)	Average	14 days (MPa)	Average	28 days (MPa)	Average
1	5.6	5.8	7.0	7.2	7.3	7.6
2	5.8		7.2		7.6	
3	5.9		7.4		7.8	

Table AIII.1c Flexural strength of plain concrete

Sample	7 days (MPa)	Average	14 days (MPa)	Average	28 days (MPa)	Average
1	4.0	4.6	5.5	5.8	6.1	6.4
2	4.2		5.8		6.3	
3	5.5		6.0		6.9	

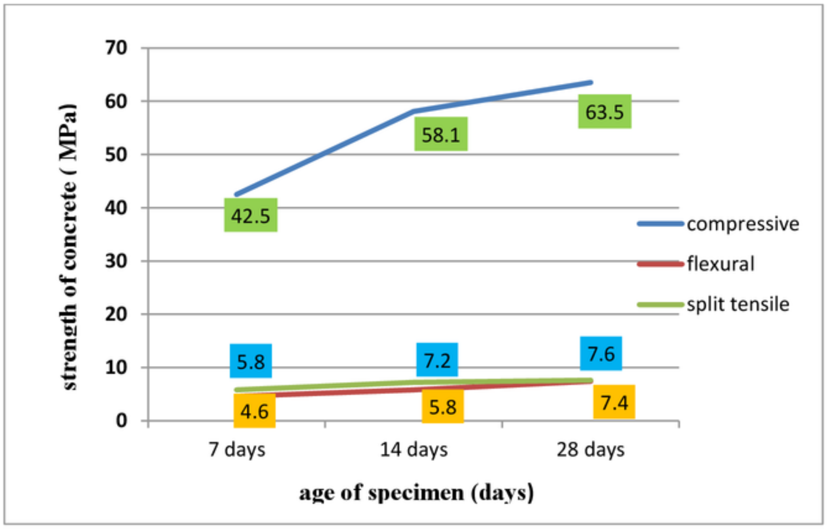

Figure AIII.1 strength of concrete in MPA Vs age of specimen in Days

AIII.2 M60 grade Polypropylene Fibre Reinforced Concrete (PFRC)

Table AIII.2a Average Compressive strength of PFRC

Fibre content	7 days (MPa)	14 days (MPa)	28 days (MPa)
0.5 %	50	67.8	74.7
1.0 %	48.1	66.9	71.8
1.5 %	47.8	66.8	70.8

Table AIII.2b Average Split tensile strength of PFRC

Fibre content	7 days (MPa)	14 days (MPa)	28 days (MPa)
0.5 %	8.3	10.5	11.3
1.0 %	7	8.1	8.6
1.5 %	6.5	7.8	8.5

Table AIII.2c Average Flexural strength of PFRC

Fibre content	7 days (MPa)	14 days (MPa)	28 days (MPa)
0.5 %	6.4	7.7	8.6
1.0 %	5.5	6.8	7.2
1.5 %	5.1	6.3	7.1

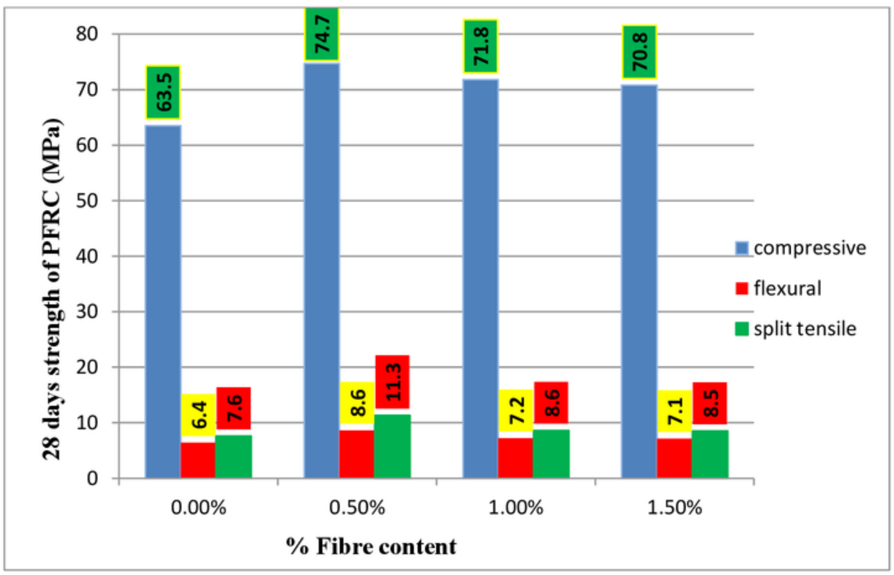

Figure AIII.2 28 days strength of PFRC in MPa Vs % Fibre content

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