SUITABILITY OF CONCRETE REINFORCED WITH SYNTHETIC FIBER

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CERTIFICATE

This is to certify that the work entitled **"SUITABILITY OF CONCRETE REINFORCED WITH SYNTHETIC FIBER"** submitted by **Angaddeep Singh (111708) & Akhil Bhatt (111601),** in partial fulfilment for the award of degree of Bachelor of Technology in Civil Engineering of Jaypee University of Information Technology, Waknaghat has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma to the best of my knowledge.

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We gratefully acknowledge the Management and Administration of Jaypee University of Information Technology, Waknaghat for providing us the opportunity and hence the environment to initiate and complete our project now.

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ABSTRACT

Addition of fiber reinforcement in discrete form improves many engineering properties of concrete. Currently Fiber reinforced concrete (FRC) is a new structural material which is gaining increasing importance. Very little research work is being conducted in India using this new material. This report describes the use of synthetic fibers and the comparison of PCC & FRC is made on the basis of different mechanical properties.

Shrinkage cracking of concrete is a major problem in plain cement concrete especially in tropical regions. To overcome shrinkage cracking of plain concrete, the addition of synthetic fiber to the concrete mix is suggested. This report briefly discusses the effects of addition of polypropylene fibrillated fibre on the properties of concrete mix of 20 Mpa.. Concrete mixes with fiber dosage 0.10%, 0.2% and 0.3% by volume fraction besides the control concrete mix were manufactured. Fibrillated polypropylene fiber was used in this study. The properties such as workability, compressive strength & split tensile strength of the concrete were evaluated. The study suggested a significant reduction in settlement without significant change in compressive strength for the concrete mixes reinforced with fiber. Further, an improved spilt tensile strength for the concrete mixes reinforced with fiber was also observed.

CHAPTER 1

INTRODUCTION

INTRODUCTION

Plain portland cement concrete exhibits brittle behaviour. Consequently, the material possesses a low tensile strength as well as a low tensile strain capability. Concrete is prone to have numerous micro- and macro-cracks during its setting and hardening process. Use of synthetic fiber in concrete has been advocated by several researchers for improving some specific properties of the concrete. Thoroughly mixed and dispersed microfibers are effective in reducing plastic shrinkage cracking as they delay the process by which the micro cracks coalesce to form large, macroscopic cracks known as macro cracks. In this way, the addition of synthetic fibers modifies the properties of concrete matrix. Polypropylene (PP) fiber is widely used for this purpose in the construction industry. The effect of fibers on the properties of concrete varies depending on their type, length, aspect ratio, concrete mix etc.

The concept of using fibers to improve the characteristics of construction materials is very old. Early applications include addition of straw to mud bricks, horse hair to reinforce plaster and asbestos to reinforce pottery. The modern development of fiber reinforced concrete (FRC) started in the early sixties. Addition of fibers to concrete makes it a homogeneous and isotropic material. When concrete cracks, the randomly oriented fibers start functioning, arrest crack formation and propagation, and thus improve strength and ductility. The failure modes of FRC are either bond failure between fiber and matrix or material failure.

Polypropylene fibers are available in three different forms; Monofilaments, Multifilament and Fibrillated. Monofilament fibers are single strand of fibers having uniform cross-sectional area and produced in an extrusion process Multifilament is a yarn consisting of a number of continuous filaments or strands. Most textile filament yarns are multifilament. The diameters of the multifilament fibers depend on the number of monofilament fibers used, and how they are combined to form a yarn. Fibrillated fibers are manufactured in the form of films or tapes that are slit in such a way that they can be expanded into an open network to allow penetration of cementitious materials. Fibers are finally cut to the desired lengths. During the mixing, due to friction with aggregates, the fibrillated fiber expands in to a net.

Several researchers have reported that finer Polypropylene fiber is more effective in reducing the width of plastic shrinkage cracking than coarser fiber. The compressive and tensile strength of the concrete reinforced with low volume of polypropylene fiber are not significantly different from those of the unreinforced matrix. Some researchers have reported increase in flexural strength of concrete reinforced with PP fiber. Very limited works on concrete reinforced with fibrillated fibre are reported in literature. In the present study, the effect of addition of polypropylene fibrillated fiber on workability, compressive strength, and split tensile strength of concrete mix with respect to unreinforced concrete mix has been evaluated and discussed.

NOTE:-Our study is limited to only M20 grade concrete, which is chosen by us to conduct various experiments, as it is most widely used in day-to-day life. Also, the comparison made is limited to few studies only. Moreover, only three mechanical properties of concrete are compared and analysed.

1.1 History of Fiber Reinforced Concrete

Fibers have been used for concrete reinforcement since prehistoric times though technology has improved significantly, as is applicable for other fields. In the early age, straw and mortar were used for producing mud bricks, and horsehair was used for their reinforcement. Natural fibers such as pine needles and wheat straws are shown in Fig. 1.1 As the fiber technology developed, cement was reinforced by asbestos fibers in the early twentieth century. During the middle of the twentieth century, extensive research was in progress for the use of composite materials for concrete reinforcement. Later, the use of asbestos for concrete reinforcement was discouraged due to the detection of health risks. New materials like steel, glass, and synthetic fibers replaced asbestos for reinforcement. Active research is still in progress on this important technology. Fiber Reinforced Concrete is considered to be one of the greatest advancements in the construction engineering during the twentieth century.

(a) Pine needles **(b) Wheat straws**

Figure 1.1: Natural Fibers

1.2 Types of Fibers

Now a days many different types of fibers are being used which have different properties and can be used as per the desired conditions. Various types of fibers are discussed below.

a. <u>Glass Fiber Reinforced concrete (GFRC)</u>

Glass fiber reinforced concrete has been successfully used since the last 25 years for concrete reinforcement, in addition to steel. GFRC is being manufactured into big panels with a simple configuration or into intricate shapes by using special techniques. A pictorial view of glass fiber is shown in fig 1.2 below. Originally, GFRC components were anchored directly with the buildings by the use of metal studs. It was revealed that GFRC shifts considerably due to which the direct anchors are being replaced by slip anchors. Several structures use GFRC for dissimilar facing like ceramic tiles, bricks, and architectural purposes.

Figure 1.2: Glass Fiber

b. <u>Steel Fiber Reinforced Concrete (SFRC)</u>

Steel fiber reinforced concrete is a composite material that can be sprayed. It consists of hydraulic cements with steel fibers that are dispersed randomly and possess a rectangular cross-section. The steel fibers reinforce concrete by withstanding tensile cracking. Fig. 1.3 shows a pictorial view of steel fibers. The flexural strength of fiber reinforced concrete is greater than the un-reinforced concrete. Reinforcement of concrete by steel fibers is isotropic in nature that improves the resistance to fracture, disintegration, and fatigue. Steel fiber reinforced concrete is able to withstand light and heavy loads.

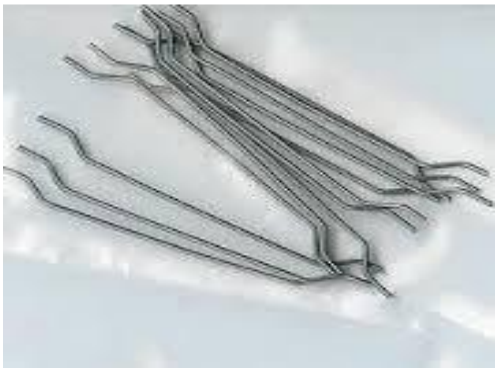


Figure 1.3: Steel Fiber

c. <u>Natural fiber reinforced concrete (NFRC)</u>

It consists of cellulose fibers that are processed from pine trees and wheat straws as shown in Fig. 1.1. This category is also producing good results. The recycled carpet waste has been successfully used for concrete reinforcement by using the waste carpet fibers.

d. <u>Asbestos Fibers</u>

These fibers are cheap and provide the cement with mechanical, chemical and thermal resistance, although the asbestos fiber reinforced concrete appears to have low impact strength. Pictorial view of Asbestos fiber is shown below in Fig. 1.4.

Figure 1.4: Asbestos fibers

e. <u>Carbon Fibers</u>

These fibers have been recently used due to their very high modulus of elasticity and flexural strength. Characteristics such as strength and stiffness are better than those of steel fibers, although they are more susceptible to damage as shown in Fig. 1.5.

Figure 1.5: Carbon Fiber

f. <u>Synthetic Fibers</u>

In today's world, synthetic fibers are mostly used in various fields. There are many types of synthetic fibers and few are discussed below, namely, polypropylene fiber, nylon fiber and polyester fiber.

i).Polypropylene Fiber Reinforced concrete: Of the synthetic fibers available, polypropylene is the most widely used in ready mixed concrete. Polypropylene fibers are hydrophobic, so they don't absorb water and have no effect on concrete mixing water requirements. They come as either fibrillated bundles or monofilaments. To produce fibrillated fibers, manufacturers extrude the polypropylene in sheets that are stretched and slit. The result is a mesh of interconnected fiber strands rectangular in cross section. Manufacturers cut the strands to specified lengths and separate them into bundles. Fiber lengths range from 1⁄4 to 21⁄2 inches. When added to concrete during mixing, the fibrillated fibers open into a network of linked fiber filaments that mechanically anchor to the cement paste. The graded fibers reportedly disperse more thoroughly into all areas of the cement paste during mixing. Monofilament fibers are fine, cylindrical strands that separate during mixing. Because monofilament fibers are smooth and have a small surface area, they don't anchor into the cement matrix as well as fibrillated fibers. With fibrillated fibers, cement paste penetrates into the network of fiber filaments resulting in better mechanical anchoring to the concrete. Research shows that lower volumes of fibrillated fibers than of monofilament fibers are needed to improve the post-cracking load carrying capacity and ductility of concrete. Some manufacturers recommend using monofilament fibers for relatively short-term benefits, such as plastic shrinkage crack control during the first few hours after concrete placement.

ii). Polyester The fiber bundles come only in monofilament form in lengths from 3 ⁄4 to 2 inches . Like polypropylene, polyester fibers are hydrophobic. However, they have a tendency to disintegrate in the alkaline environment of portland cement concrete. To retard this degradation, manufacturers of polyester fibers coat the fibers to resist alkali attack. But the long-term performance of the coated fibers has not been determined. A pictorial view of polyester fiber is shown below in Fig. 1.6.

Figure 1.6: Polyester Fiber

iii). Nylon. Like poly-ester fibers, nylon fibers come only in monofilament form. They are of hydrophilic nature. They retain a natural moisture balance of 4.5%. Because of this strong affinity to water, nylon fibers bond chemically to the concrete matrix. The bond of polypropylene and polyester fibers is only mechanical. Nylon fiber manufacturers also report that their fibers have higher aspect ratios than those made of polypropylene. Therefore, they can be added in smaller dosages to produce the same reinforcing effects. Usually no more than 1 pound per cubic yard is needed. Fig. 1.7 depicts the nylon fiber.

Figure 1.7: Nylon Fiber

CHAPTER 2

LITERATURE REVIEW

LITERATURE REVIEW

Use of synthetic fiber in concrete has been advocated by several researchers (Bentur and Mindess 2007; Balaguru and Shah, 1992; Banthia and Gupta 2006 etc.) for improving some specific properties of the concrete. Thoroughly mixed and dispersed microfibers are effective in reducing plastic shrinkage cracking as they delay the process by which the micro cracks coalesce to form large, macroscopic cracks known as macro cracks (Lawler et al, 2002). In this way, the addition of synthetic fibers modifies the properties of concrete matrix. Synthetic fibers are most commonly added to concrete for slab-on-grade construction to reduce early plastic shrinkage cracking and increase impact and abrasion resistance and toughness. Polypropylene (PP) fiber is widely used for this purpose in the construction industry (Zollo, 1984). The effect of fibers on the properties of concrete varies depending on their type, length, aspect ratio, concrete mix etc. Few studies are discussed below briefly and they are compared with present study in Chapter-5.

2.1 Introduction to Steel Fiber Reinforced Concrete

V.S. Vairagade & K.S. Kene, 2012, conducted number of laboratory experiments to check enhancement in various mechanical properties of concrete such as compressive strength, flexural strength, split tensile strength, toughness, workability using different percentage of steel fibers.on the basis of their study they concluded that Steel fibers improves tensile & flexural strength, shock & fatigue resistance, ductility & crack arrest. Workability was reduced because steel fibers formed a network structure in concrete which restrain the mixture from flowing. So addition of super plasticisers was recommended.

An increase of 6% to 17% in compressive strength, 18% to 47% increase in split tensile strength, 22% to 63% increase in flexural strength and 18% to 24% increase in toughness of concrete is seen using steel fibers in various concrete grades.

2.2 FRC Using Waste Plastics as Fibers

R. Kandasamy & R. Murugesan, 2011, made an attempt to study the influence of addition of polythene fibers (Domestic waste plastic) at a dose of 0.5% by wt. of cement. The properties studied include compressive strength and flexural strength of M20 mix.

Following conclusions were made by them on the basis of experimental results:

Addition of 0.5% of polythene fiber to concrete increases the cube compressive strength of concrete in 7 days to an extend of 0.68%, increases the cube compressive strength of concrete in 28 days to an extend of 5.12%, increases cylinder compressive strength of concrete in 28 days by 3.84% and increase in split tensile strength to an extend of 1.63%.

2.3 Using Polypropylene Fiber

Rakesh Kumar, et al., 2013, in their paper briefly discussed the effects of addition of polypropylene discrete and fibrillated fibre on the properties of a paving grade concrete mix of 48 MPa compressive strength at 28-day. Pictorial representation of multifilament and fibrillated fiber is shown in Fig. 2.1 & 2.2 respectively. Six concrete mixes with fiber dosages 0.05%, 0.10% and 0.15% by volume fraction besides the control concrete mix were manufactured. Discrete and fibrillated polypropylene fiber was used in this study. The properties such as settlement, compressive strength, drying shrinkage, and abrasion resistance of the concrete were evaluated.

Figure 2.1: Multifilament fiber

Figure 2.2: Fibrillated fiber

Basically they compared multifilament and fibrillated fiber performance against each other as it was proved that both are better than plain concrete. It was observed that fibrillated fiber is more effective in reducing settlement of conc. than multifilament fiber, no adverse effect on 28 day comp. strength of conc. was seen, fibrillated fiber performs better in controlling drying shrinkage than multifilament fiber, fibrillated fiber & multifilament fiber both performs similar in development of abrasion resistance.

2.4 Using Glass Fiber

R.P. Patel, et al., 2013; in their paper briefly discusses the effects of addition of glass fibre on the properties of a concrete mix of 20 MPa compressive strength at 28-day. For this purpose, fiber content of 0%, 0.03%, 0.06% and 0.1% by volume fraction of concrete was added and compression, flexural and split tensile strength at 28 days was observed. He conclude that 0.1% addition of glass fiber shows best results among all percent dosage. An increase of 8.95% and 11.16% in cube compressive strength in 7 days and 28 days was found respectively w.r.t. plain concrete. Also, an increase of 6.85% and 12.73% was observed in split tensile strength in 7 days and 28 days respectively w.r.t. plain concrete in the same study.

2.5 Concluding Remarks

Several researchers (Qi and Weiss, 2003; Banthia and Gupta, 2006) have reported that finer polypropylene fibrillated fiber is more effective in reducing the width of plastic shrinkage cracking than coarser fiber. The compressive and tensile strength of the concrete reinforced with low volume of PP fiber are not significantly different from those of the unreinforced matrix (Kumar et al., 2012; Hasaba et al., 1984; Ramakrishnan et al., 1987.) Some researchers (Hasaba et al, 1984; Banthia and Dubey, 1999; Banthia and Dubey, 2000) have reported increase in flexural strength of concrete reinforced with polypropylene fiber. Very limited works on concrete reinforced with fibrillated fibre are reported in literature. Ramakrishnan et al. 1999, observed a slight increase (0.7- 2.6%) in flexural strength of concrete reinforced with fibrillated fiber at the dosage of 0.1% by volume while at fiber content 0.2 - 0.3% by volume they observed slight decrease in flexural strength. In the present study, an attempt has been made to study the effect of addition of polypropylene fibrillated fiber on workability, compressive strength, and split tensile strength of concrete mix with respect to unreinforced concrete mix.

CHAPTER 3

SPECIFICATION & DESCRIPTION OF MATERIAL USED

SPECIFICATIONS AND DESCRIPTION OF MATERIAL USED

In order to achieve the objectives of the study, the systematic series of laboratory experiments were conducted. This chapter delas with the detailed specification and description of material used in experiments. Also the basic tests on cement, sand and aggregates are conducted and hence their suitability for further experiments is assured.

3.1 Cement Used

Portland Pozzolana cement (PPC) (IS 1489–1991) is manufactured by the intergrinding 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 silicious 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 2 of 1991) or fly ash (IS 1489 part I of 1991). Fly ash is a waste material, generated in the thermal power station, when powdered coal is used as a fuel. These are collected in the electrostatic precipitator. (It is called pulverised fuel ash in UK).

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. Portland pozzolana cement can generally be used where ordinary Portland cement is usable. However, it is important to appreciate that the addition of pozzolana does not contribute to the strength at early ages. Strengths similar to those of ordinary Portland cement can be expected in general only at later ages provided the concrete is cured under moist conditions for a sufficient period.

In India there is apprehension in the minds of the user to use the Portland pozzolana cement for structural works. It can be said that this fear is not justified. If the Portland pozzolana cement is manufactured by using the right type of reactive pozzolanic material, the Portland pozzolanic cement will not be in any way inferior to ordinary Portland cement except for the rate of development of strength upto 7 days. It is only when inferior pozzolanic materials, which are not of reactive type and which do not satisfy the specifications limit for pozzolanic materials, are used the cement would be of doubtful quality.

APPLICATION

Portland pozzolana cement can be used in all situations where OPC is used except where high early strength is of special requirement. As PPC needs enough moisture for sustained pozzolanic activity, a little longer curing is desirable. Use of PPC would be particularly suitable for the following situations:

(a) For hydraulic structures;

(b) For mass concrete structures like dam, bridge piers and thick foundation;

(c) For marine structures;

(d) For sewers and sewage disposal works etc.

3.1.1 Tests on Cement

a). Soundness Test

In the soundness test a specimen of hardened cement paste is boiled for a fixed time so that any tendency to expand is speeded up and can be detected. Soundness means the ability to resist volume expansion.

Following are the results and calculations of laboratory Lechatliers test conducted by us:

Soundness/expansion of cement = L_1-L_2

L_1=Measurement taken after 24 hours of immersion in water at a temp. of 27 ± 2^0 C

L_2=Measurement taken after 3 hours of immersion in water at boiling temperature.

L_1 = 2.2cm

L_2 = 1.9cm

Soundness = 2.2 - 1.9 = 3mm

According to IS:1489-1991(part 1) the maximum value of soundness of PPC by Le-Chateliers test method is 10 mm and our result is 3mm which indicates that cement used in this study is quite good as per soundness is concerned.

b). Normal Consistency

Standard consistency of a cement paste is defined as that consistency which will permit a vicat plunger having 10 mm dia and 50 mm length to penetrate to a depth of 33-35 mm from top of the mould.

In the lab test conducted by us, normal consistency comes out to be **35%** for PPC.

c). Initial and Final Setting Time

Initial setting time is that time period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould.

Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression.

Following are the results and calculations of laboratory test conducted by us:

Initial setting time= t_2-t_1

Final setting time= t_3-t_1,

Where,

t_1=Time at which water is first added to cement

t_2=Time when needle fails to penetrate 5 mm to 7 mm from bottom of the mould

t_3=Time when the needle makes an impression but the attachment fails to do so.

t_1 = 0 mins, t_2 = 43 mins, t_3 = 7 hrs 30 mins

So, **IST= 43 mins and FST= 7 hrs 30 mins**

The standard value of IST = 30 mins (minimum) and of FST = 600 min or 10 hrs (maximum) according to IS code. We can clearly see that our values are according to range as per mentioned in IS code.

3.2 Aggregates Used

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Earlier, aggregates were considered as chemically inert materials but now it has been recognised that some of the aggregates are chemically active and also that certain aggregates exhibit chemical bond at the interface of aggregate and paste. The mere fact that the aggregates occupy 70–80 per cent of the volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable. To know more about the concrete it is very essential that one should know more about the aggregates which constitute major volume in concrete. Without the study of the aggregate in depth and range, the study of the concrete is incomplete. Cement is the only factory made standard component in concrete. Other ingredients, namely, water and aggregates are natural materials and can vary to any extent in many of their properties. The depth and range of studies that are required to be made in respect of aggregates to Aggregates are used as per the availability nearby.

FINE AGGREGATC- Aggregate most of which passes 4.75mm IS Sieve. Fine aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies.

COARSE AGGREGATE -- Aggregate most of which is retained on 4.75 mm IS Sieve. We have used the size between 10 mm to 20 mm.

3.2.1 Tests on Aggregates

a). Specific Gravity of coarse aggregates

Aggregate specific gravity is used in a number of applications including Super pave mix design, deleterious particle identification and separation, and material property change identification.

Calculations and Results of lab tests:

Specific Gravity = Dry weight of aggregate/Weight of equal volume of water.

= 2.64 / (2.64 - 1.65) **= 2.66**

Dry weight of Aggregate = 2.64 and Weight of equal volume of water = 1.65

b). Specific Gravity of Fine Aggregates

Specific Gravity = *(D / A – (B – C))*

= (530 / (550 – 347))

= 2.61

A = weight in gm of saturated surface-dry sample

B = weight in gm of pycnometer or gas jar containing sample and filled with distilled water

C = weight in gm of pycnometer or gas jar filled with distilled water only

D = weight in gm of oven-dried sample.

According to IS : 2386 – Part – 3, the range of specific gravity of aggregates is from 2.5 to 3 and our results are within the standard range which indicates that the aggregates used are appropriate.

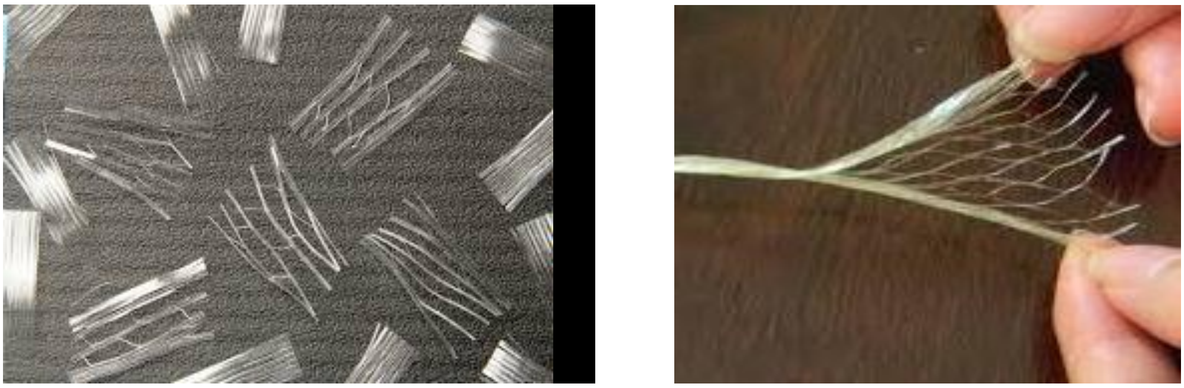
NOTE:- So, as per the results of our material used i.e. cement, coarse and fine aggregates, the material is suitable for specimen casting and further concrete tests.

3.3 Fiber Used

For this study we are using Fibermesh ® 300-e3 Micro-synthetic fiber as per its technical name and is commonly known as polypropylene fibrillated fiber. We have brought this fiber from Nina Concrete Systems Pvt. Ltd., Mumbai which is an ISO 9001 : 2001 Company. Mr. Rakesh Gupta, Fiber Quality Manager and Supplier of this company helped us to get these fibers @ Rs. 400 per 900 gram bag. The detailed description of the product is given below.

FIBERMESH® 300-e3 MICRO-SYNTHETIC FIBRE

Fibermesh® 300-e3, formerly known as Inforce™ e3®, micro-reinforcement fibres for concrete are 100 percent virgin homopolymer polypropylene graded fibrillated fibres containing no reprocessed olefin materials. Fibermesh® 300-e3 fibres are European Standard EN 14889-2:2006 compliant and have been specifically engineered and manufactured in an ISO 9001-2000.



(a) **(b)**

Figure 3.1: Pictorial Views of Polypropylene Fibrillated Fiber

<u>ADVANTAGES</u>

Non-magnetic • Rustproof • Alkali proof • Requires no minimum amount of concrete cover • Is always positioned in compliance with codes • Safe and easy to use • Saves time and hassle

FEATURES & BENEFITS

• Inhibits and controls the formation of intrinsic cracking in concrete

• Increases cohesion and reduces segregation

• Reduces settlement and bleeding

• Reduces plastic shrinkage and settlement cracking

• Increases impact and shatter resistance

• Reinforces against abrasion

• Reduces freeze/thaw damage

• Provides improved toughness/ durability

• Provides residual strength

PRIMARY APPLICATIONS

Polypropylene Fibrillated Fiber is widely used in ground supported slabs, External roads & pavements, driveways, sprayed concrete, precast, overlays and toppings, tanks & pools etc.

CHEMICAL & PHYSICAL PROPERTIES

Fibre Length	Various
Type /Shape	Graded/Fibrillated
Absorption	Nil
Specific Gravity	0.91
Electrical Conductivity	Low
Acid & Salt Resistance	High
Melt Point	162°C (324°F)

Ignition Point	593°C (1100°F)
Thermal Conductivity	Low
Alkali Resistance	Alkali Proof

HANDLING OF FIBERS WHILE CASTING

MIXING DESIGNS AND PROCEDURES:

Fibermesh® 300-e3 micro reinforcement is a mechanical, not chemical, process. The addition of Fibermesh® 300-e3 graded fibrillated fibres do not require any additional water nor other mix design changes at normal rates. Fibermesh® 300-e3 fibres can be added to the mixer before, during or after batching the other concrete materials. After the addition of the fibres, the concrete should be mixed for sufficient time (minimum 5 minutes at full mixing speed) to ensure uniform distribution of fibres throughout the concrete.

PLACING:

Fibermesh® 300-e3 micro-reinforced concrete can be pumped, sprayed or placed using conventional equipment. Hand or vibratory screeds and laser screeds can be used with Fibermesh® 300-e3 micro-reinforced concrete.

FINISHING:

Fibermesh® 300-e3 micro-reinforced concrete can be finished by any finishing technique. Exposed aggregate, broomed and tined surfaces are no problem.

DOSAGE RATE:

The recommended dosage rate for Fibermesh® 300-e3 fibres, to achieve effective performance, is 0.9 kg per cubic metre. For speciality performance please contact your local Propex Concrete Systems representative for recommendations regarding increased application rates.

GUIDELINES:

Fibermesh® 300-e3 fibres should not be used to replace structural, load bearing reinforcement. Fibermesh® 300-e3 fibres should not be used as a means of using thinner concrete sections than original design. Fibermesh® 300-e3 fibres should not be used to increase joint spacing past those dimensions suggested for un-reinforced concrete.

COMPATIBILITY

Fibermesh® 300-e3 fibres are compatible with all concrete admixtures and performance enhancing chemicals, but require no admixtures to work.

SAFETY

No special handling is required with Fibermesh® 300-e3 fibres. Full Material Safety Data Sheets are available on request.

PACKAGING

Fibermesh® 300-e3 fibres are available in standard 0.9 kg degradable paper bags, which are designed to be placed directly into the concrete mixer without opening. They are also available upon request in a variety of packaging options to suit application. Fibermesh® 300-e3 fibres are packaged, packed into cartons, shrink wrapped and palletized for protection during shipping.

SPECIFICATION CLAUSE

Fibres for concrete shall be Fibermesh® 300-e3 micro-synthetic graded fibrillated fibres (100 percent virgin polypropylene fibres produced to ISO 1873-PP-H classification code FN 28-02-045 and containing no reprocessed olefin materials) conforming to EN 14889-2: 2006 Class Ib and specifically engineered & manufactured in an ISO 9001-2000 certified facility for use as concrete secondary reinforcement. The fibre manufacturer must document: evidence of a minimum of 5 years satisfactory performance history and certify a minimum Average residual Strength (ARS) of 0.35MPa according to ASTM 1399.

CHAPTER 4

EXPERIMENTAL SETUP & PROCEDURE

INTRODUCTION

Detailed descriptions about the materials used are discussed and explained in previous chapter. As we know, specimen details and testing methods are essentials for an experimental investigation. Hence they are described in detail in the following sections.

4.1 Experimental Investigation

Details of specimens

For all tests in this study we have use M20 concrete of standard mix proportion of 1:1.5:3 as per cement : fine aggregates : coarse aggregates and w/c ratio is taken as 0.5.

Table 4.1 shows the details of the various test specimens. It is intended to find experimentally the effect of addition of polypropylene fibers on the properties of concrete to be used for construction purpose. Hence the investigations are taken up to evaluate workability, compressive strength and split tensile strength of plain and fiber reinforced concrete specimens as per standards.

Casting and curing of specimens

The constituent materials of concrete, viz., Cement, Sand and aggregates were tested as per the relevant Indian codes. Concrete of M20 grade was designed. Concrete was mixed in a tilting type drum mixer and the specimens were cast as per the recommendations of IS: 516 - 1959. Standard steel moulds were used for casting of cubes of size 150 mm x 150 mm x 150 mm and casting of cylinders of 150 mm diameter and 300 mm height

Concrete was placed uniformly over the length of the mould in three layers and compacted satisfactorily. After compacting the entire concrete, the excess concrete at the top of the mould was stuck off with a wooden straight edge and the top finished by a trowel. Demoulding was done after 24 hours and the specimens were cured under water. After 7days and 28days, the cube specimens were removed from curing tank and taken for testing. After 28days, the cylinder specimens were removed from tank and taken for testing.

Table-4.1. Details of Experimental Specimen

S.No.	Name of Test	Specimen/Apparatus	% of fiber added	No. of specimens/test
1.	Slump test (On fresh concrete)	Top dia=100mm Bottom dia=200mm Heigth = 300mm	0% 0.1% 0.2% 0.3%	3 times 3 times 3 times 3 times
2.	Compressive Strength Test (7 days & 28 days)	Cube 15ommx150mmx150mm	0% 0.1% 0.2% 0.3%	6 6 6 6
3.	Split Tensile Test (7 days & 28 days)	Cylinder 150mm dia &300mm height	0% 0.1% 0.2% 0.3%	6 6 6 6

4.2 Testing Methods Details

The slump test for the workability of fresh concrete and 7 days and 28 days compressive strength and split tensile strength tests are conducted in this study and testing methods details are given in detail in this chapter.

4.2.1 Slump Test

As we know that in slump test three types of slumps can be obtained i.e. true slump, shear slump or collapse slump. But we only consider true slump value and discard the other two. Also we have chosen this test for workability because our w/c ratio is medium i.e neither too high nor too low. Moreover this test is easy to conduct and is available in our laboratory.

APPARATUS

The appartus for conducting the slump test essentially consists of a metallic mould in the form of a frustum of a cone having the internal dimensions : Bottom diameter : 200 mm, Top diameter : 100 mm, Height : 300 mm. The thickness of the metallic sheet for the mould should not be thinner than 1.6 mm. A steel tamping rod of 16 mm dia and 0.6 meter long with bullet end is used.

PROCEDURE

i) To obtain a representative sample, take samples from two or more regular intervals throughout the discharge of the mixer or truck. DO NOT take samples at the beginning or the end of the discharge.

ii) Dampen inside of cone and place it on a smooth, moist, non-absorbent, level surface large enough to accommodate both the slumped concrete and the slump cone. Stand or, foot pieces throughout the test procedure to hold the cone firmly in place.

iii) Fill cone 1/3 full by volume and rod 25 times. Distribute rodding evenly over the entire cross section of the sample.

iv) Fill cone 2/3 full by volume. Rod this layer 25 times with rod penetrating into, but not through first layer. Distribute rodding evenly over the entire cross section of the layer.

v) Fill cone to overflowing. Rod this layer 25 times with rod penetrating into but not through, second layer. Distribute rodding evenly over the entire cross section of this layer.

vi) Remove the excess concrete from the top of the cone, using tamping rod as a screed. Clean overflow from base of cone.

vii) Immediately lift cone vertically with slow, even motion. Do not jar the concrete or tilt the cone during this process. Invert the withdrawn cone, and place next to, but not touching the slumped concrete. (Perform in 5-10 seconds with no lateral or torsional motion.)

viii) Lay a straight edge across the top of the slump cone. Measure the amount of slump in mm from the bottom of the straight edge to the top of the slumped concrete at a point over the original centre of the base. The slump operation shall be completed in a maximum elapsed time of 2 1/2 minutes.

(a)Filling cone with fresh conc. **(b)Lifting cone after filling**

Figure 4.1: Pictorial view of Slump test in laboratory

(a)Plain concrete **(b)FRC with 0.3% fiber**

Figure 4.2:- Difference in slump values of plain and reinforced concrete

Above figures clearly shows the difference in the heights of slumps and hence the slump values of concrete with different percentage of fiber. The falling height of slump keeps on decreasing as we keep on increasing the fiber content. The detailed results of slump test are shown in Appendix-A in tabular form.

4.2.2 Compressive Strength Test

PROCEDURE

1. Placing the specimen:

i) Place the plain (lower) bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block.

ii) Wipe clean the bearing faces of the upper and lower bearing blocks and of the test specimen. Place the test specimen on the lower bearing block.

iii) Carefully align the axis of the specimen with the centre of thrust of the spherically seated block.

iv) As the spherically seated block is brought to bear on the specimen, rotate its movable portion gently by hand so that uniform seating is obtained.

2. Rate of loading:

i) Apply the load continuously and without shock. Apply the load at a constant rate within the range of 4 to 8 kN per second. During the application of the first half of the estimated maximum load, a higher rate of loading may be permitted.

ii) Do not make any adjustment in the controls of the testing machine while the specimen is yielding rapidly immediately before failure.

iii) Increase the load until the specimen yields or fails and record the maximum load carried by the specimen during the test.

iv) Note the type of failure and the appearance of the concrete if other than the usual cone type fracture.

(a)Placing specimen on CTM **(b)Cracks after failure**

Figure 4.3: Cube Compressive Strength test in laboratory

(a)Plain concrete cube specimen **(b)Cube specimen with 0.1% fiber content**

Figure 4.4: Different Cube specimen after 28 days compressive strength test

In the above figures, compression test in lab conducted by us is shown. The detailed values of results obtained are given in tabular form in Appendix-B. Moreover, the comparison and analysis of these results is done in Chapter-5.

4.2.3 Split Tensile Test

PROCEDURE

i) Take mix proportion as 1:1.5:3 with water cement ratio of 0.6. Take cylinders of the size 150mm diameter X 300 mm length. Mix at least for two minutes.

ii) Pour concrete in moulds oiled with medium viscosity oil. Fill the cylinder mould and place them on table vibrator till smooth surface is obtained.

iii) Remove the surplus concrete from the top of the moulds with the help of the trowel.

iv) Cover the moulds with wet mats and put the identification mark after about 3 to 4 hours.

v) Remove the specimens from the mould after 24 hours and immerse them in water for the final curing. The test are usually conducted at the age of 7-28 days. The time age shall be calculated from the time of addition of water to the dry ingredients.

vi) Test at least three specimens for each age of test as follows.

TESTING ON CTM

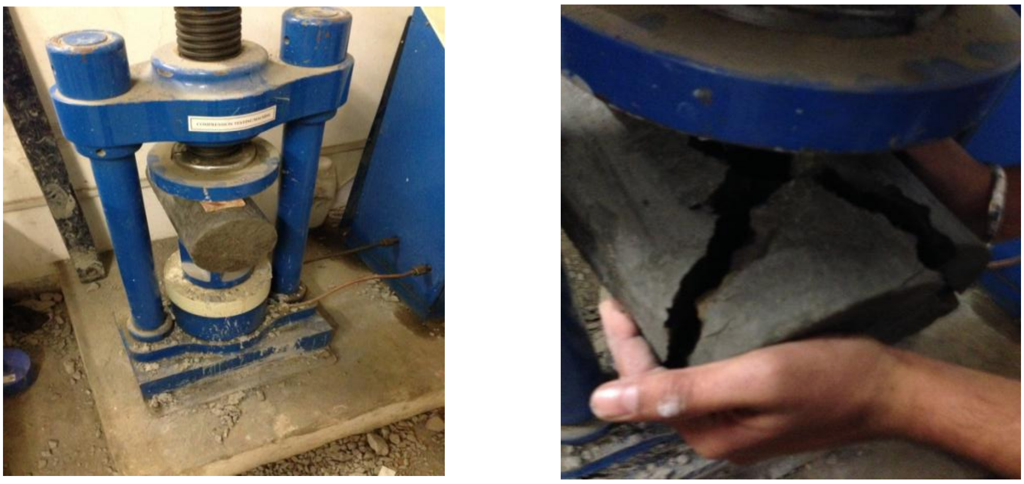
i. Draw diametrical lines on two ends of the specimen so that they are in the same axial plane.

ii. Centre one of the plywood strips along the centre of the lower platen. Place the specimen on the plywood strip and align it so that the lines marked on the end of the specimen are vertical and centred over the plywood strip. The second plywood strip is placed length wise on the cylinder centred on the lines marked on the ends of the cylinder.

iii. Apply the load without shock at a constant rate to produce a split tensile stress, until no greater load can be sustained. Record the maximum load applied to specimen.

iv. Note the appearance of concrete and any unusual feature in the type of failure.

v. Compute the split tensile strength of the specimen to the nearest 0.25 N/mm^2.



(a)Placing of specimen on CTM **(b)Specimen after failure**

Figure 4.5: Split Tensile Test on Cylindrical Specimen

(a)Plain concrete failure pattern **(b) FRC with 0.1% fiber failure pattern**

Figure 4.6 : Different failure patterns of plain and FR concrete after 28 days test

The results of split tensile test conducted on cylindrical specimen of M20 grade concrete with different percentage of fiber content is shown in tabular form in Appendix-C and the comparison and analysis of results is done in Chapter-5.

CALCULATION

Calculate the splitting tensile strength of the specimen as follows:

$$T = 2P/\pi l d$$

Where:

♦ T = splitting tensile strength, kPa

♦ P = maximum applied load indicated by the testing machine, kN

♦ l = length, m

♦ d = diameter, m

4.3 Calculation of Percentage of Fiber to be added

x% of fiber in concrete (vol./vol.)

It means adding x% volume of fiber in 100% volume of concrete. So, taking 1 m^3 of concrete and 0.1% fiber.

1 m^3 of concrete contains 1/1000 m^3 of fiber

So, 1000 m^3 of concrete contains 1 m^3 of fiber

Similarly, 1000 cm^3 of concrete contains 1 cm^3 of fiber

Since, Specific gravity of fiber = 0.9

Therefore, 1000 cm^3 of concrete contains 1 x 0.9 = 0.9 gm of fiber.

Now,

Vol. of one cube specimen = 15 x15 x 15 = 3375 cm^3

Vol. of 6 cube specimen = 3375 x 6 = 20250 cm^3

Vol. of one cylindrical specimen = $\pi R^2 h$ = 3.14 x 7.5^2 x 30 = 5300 cm^3

Vol. of 6 cylindrical specimen = 5300 x 6 = 31800 cm^3

Total vol. of concrete casted at once = 20250 + 31800 = 52050 cm^3

Therefore, weight of 0.1% fiber required = 0.9 x 52050/1000 = 46.845 gm = 47 gm

Considering losses that some of the fiber get sticked to the inner surface of mixer, we have added 50 gm of fiber as 0.1% fiber.

Similarly, to calculate the weigth required for 0.2% and 0.3% fiber multiply that of 0.1% with 2 and 3 respectively i.e. 2 x 50 = 100 gm for 0.3% and 3 x 50 = 150 gm

CHAPTER 5

ANALYSIS OF DATA & DISCUSSION OF RESULTS

INTRODUCTION

Particularly three tests i.e. slump test, cube compressive strength test and cylinder split tensile strength test are conducted by us in the Concrete Laboratory of Civil Engineering Department of Jaypee University of Information Technology, Waknaghat. The results are analysed and discussed as under.

5.1 Properties of Plain Concrete

The mechanical properties of M20 plain concrete such as workability, compressive strength and split tensile strength were observed by various tests in concrete laboratory. These results are shown below in tabular form.

Table 5.1 : Results of various experiments on M20 concrete

S. No.	Experiments	Observed & Calculated Results	Standard Results
1.	Slump Test	50 mm	50 mm to 100 mm for Medium workability mixes
2.	Compressive Strength Test 7 days 28 days	 22.7 N/mm^2 32.25 N/mm^2	 $\geq$ 19.5 N/mm^2 $\geq$ 26.6 N/mm^2
3.	Split Tensile Strength Test 7 days 28 days	 1.1 N/mm^2 2.85 N/mm^2	 $\geq$ 1.0 N/mm^2 $\geq$ 2.6 N/mm^2

From the above table we can observe that our results for M20 plain concrete are suitable as per standard results are concerned. Now in the following section, we will discuss and compare the results of plain and fiber reinforced concrete with varying percentage of fiber in detail.

5.2 Properties of Concrete on Adding Fibers

As explained earlier that Slump test is used to check the workability of concrete, especially with medium w/c ratio. So, in laboratory we performed the slump test thrice for each type of fresh concrete i.e. plain concrete and concrete with different percentage of fiber and got the following slump values as result.

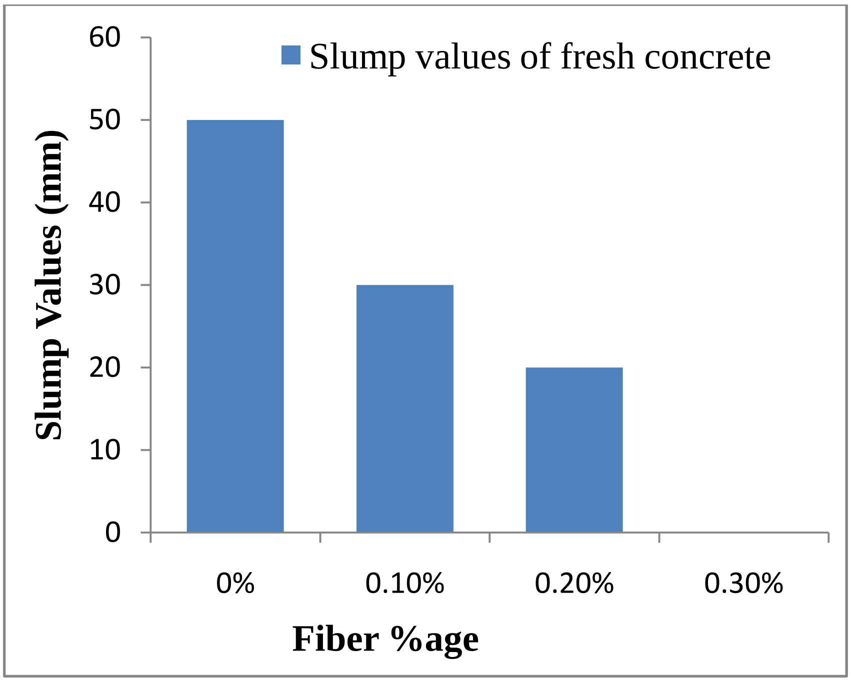


Figure 5.1: Chart representation of Slump test results with varying %age of fiber

As it is seen that the slump value for plain concrete comes out to be 50 mm and for the fiber reinforced concrete its value is decreasing with the increase in the percentage of fiber added. The test results of slump are shown in Appendix-A. As same amount of water is added in all the cases, so results show that the addition of fiber has a detrimental effect on the workability of concrete mix. Increase in slump reduction is there with increase of fiber content. This reduction in slump value and hence settlement of concrete containing fiber may be attributed to the action of fibers in the mix similar to the formation of a three- dimensional sieve, stopping the air passing up through the sieve and preventing the aggregate from pass down. That’s why zero slump value is seen when 0.3% fiber was added to concrete.

As we all know that compressive strength is one of the most important properties of concrete and influences many other describable properties of hardened concrete. Cubes were tested on Compressive Testing Machine (CTM), for 7 days and 28 days and the results are plotted below. Moreover, comparison is made to find out the optimum fiber content and the exact values can be found in the tables in Appendix.

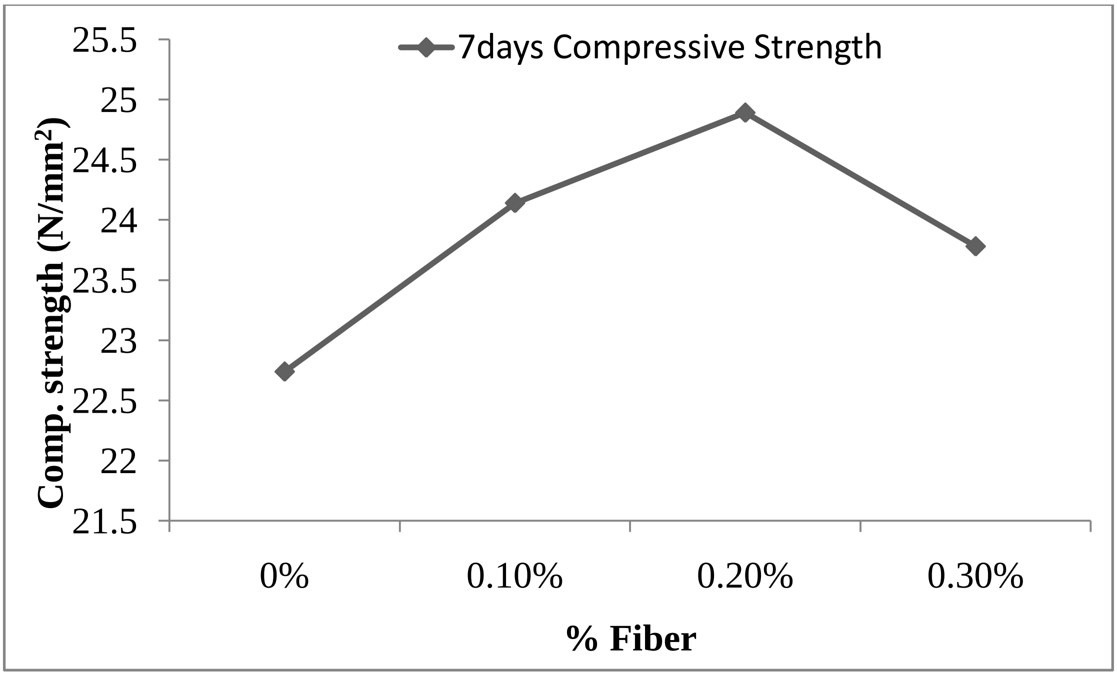


Figure 5.2: Graphical representation of 7 days compressive strength at varying percentage of fiber

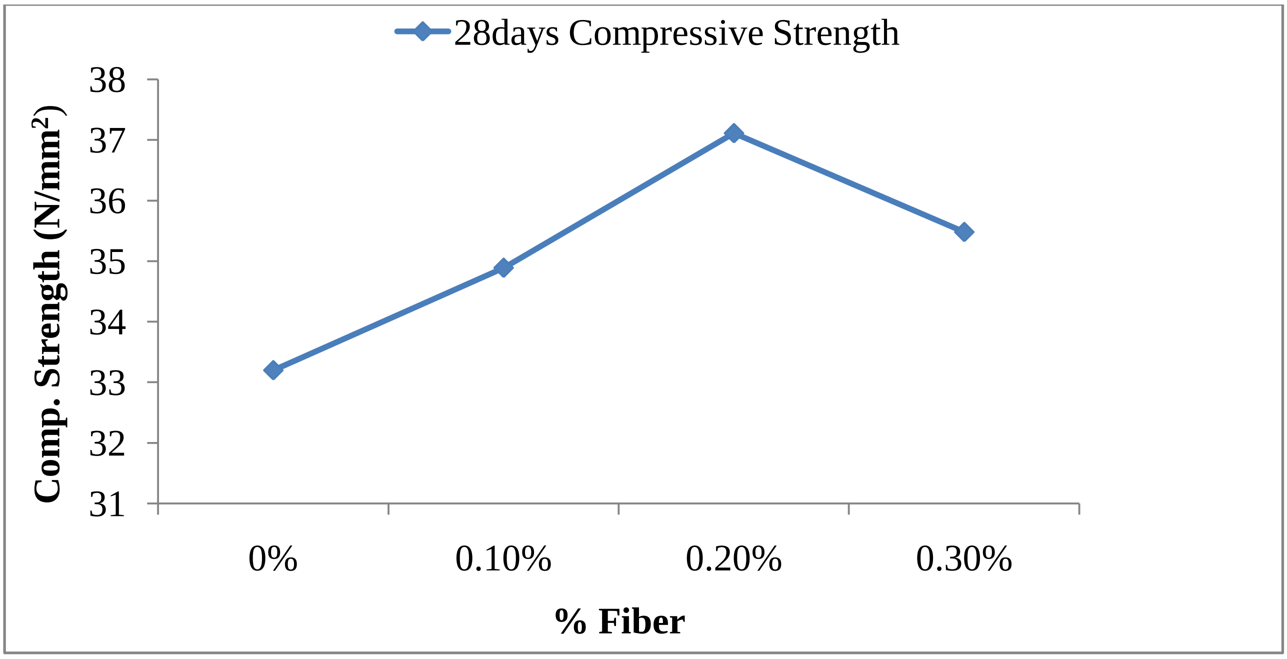


Figure 5.3: Graphical representation of 28 days split tensile strength at varying percentage of fiber

The influence of the addition of 0.1%, 0.2% and 0.3% fiber on the mixes tested is compared with plain concrete mix and the results are tabulated in Tables shown in Appendix-B. It is seen that the maximum average increase in 7 days compressive strength of M20 concrete is 9.45% w.r.t. plain concrete at 0.2% fiber content. Whereas with 0.1% and 0.3% fiber content, average increase in 7 days compressive strength is 6.2% and 4.6% respectively w.r.t. plain concrete. Also, maximum increase in 28 days compressive strength of M20 concrete is 11.78% w.r.t. plain concrete and that too at 0.2% fiber content. At with 0.1% and 0.3% fiber content, average increase in 28 days compressive strength is 5.1% and 6.87% respectively. It is well established that addition of fibres significantly contributes to the improvements in the compressive strength of concrete and the results of the present study also indicate the same. From our experiments we also conclude that the compressive strength keeps on increasing as we keep on adding the fibers till 0.2%, but after that the strength starts decreasing as the fibers replaces other materials. So, we get a term known as Optimum Fiber Content (OFC) for which we get maximum compressive strength for M20 grade concrete and its value is 0.2% of fibers w.r.t. total mix.

Similarly for split tensile test, cylinders were cast and these were tested on CTM, for 7 days and 28 days and the results are plotted below. Moreover, comparison is made to find out the optimum fiber content and the exact values can be found in the tables in Appendix-C.

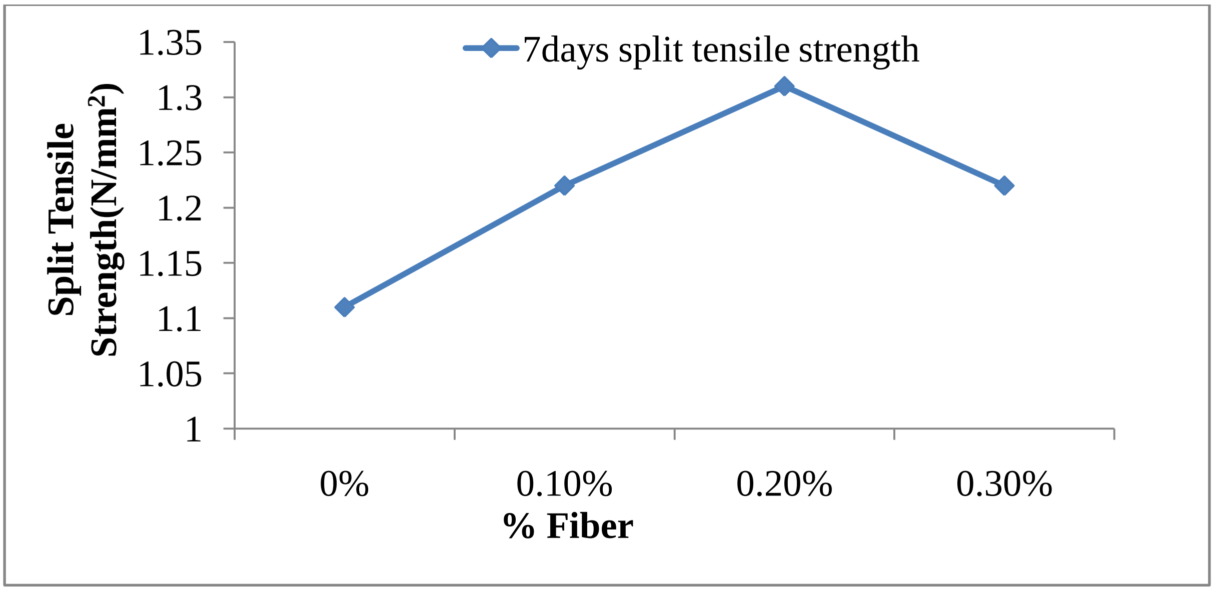


Figure 5.4: Graphical representation of 7 days split tensile strength at varying percentage of fiber

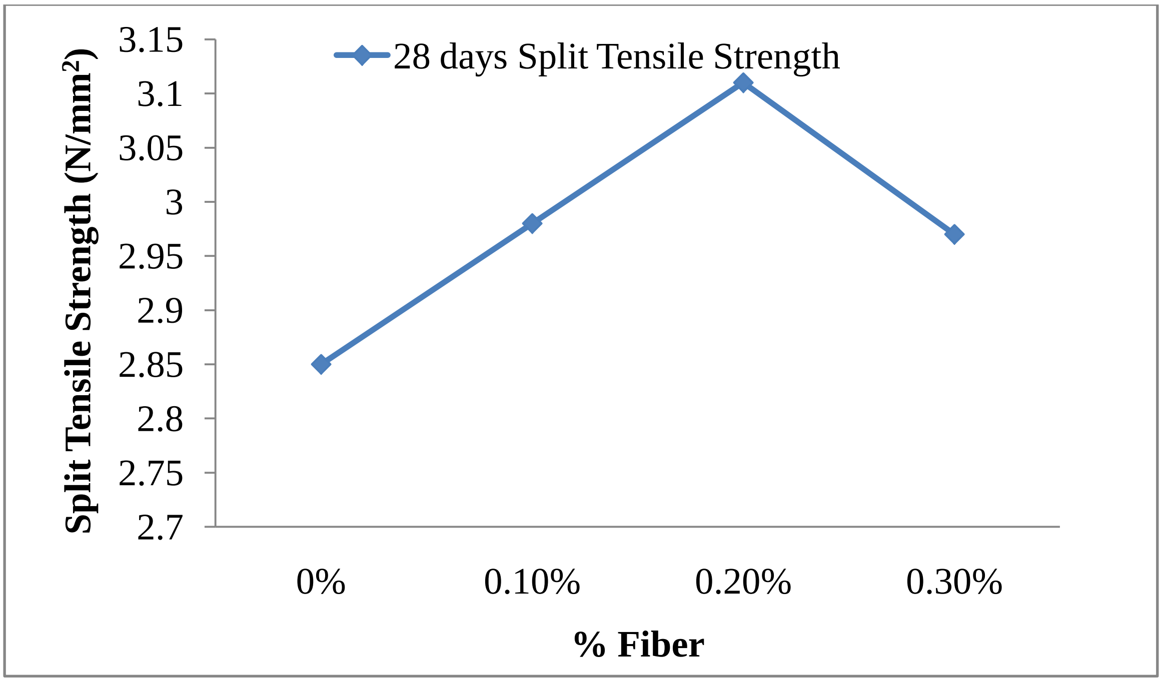


Figure 5.5: Graphical representation of 28 days split tensile strength at varying percentage of fiber

Tables given in Appendix-C shows the comparison results of split tensile strength of the concrete mixes with different percentage of fiber content. It is seen from the Tables that the maximum average increase in 7 days split tensile strength of M20 concrete is 18.01% w.r.t. plain concrete at 0.2% fiber content. Also, maximum increase in 28 days compressive strength of M20 concrete is 9.12% w.r.t. plain concrete and that too at 0.2% fiber content, which is a very significant increase. Also, increase in 7 days and 28 days split tensile strength with 0.1% and 0.3% fiber is 9.9%, 9.9%, 4.56% and 4.21% respectively which is also a good and reliable result. Similarly, here also we get OFC as 0.2% for M20 concrete.

5.3 Comparison of Results with Previous Studies

In order to compare the effect of PP fibre with waste plastic fibre and glass fibre on concrete, the results of R. Kandasamy and R. Murugesan (2011) and R.P. Patel, et al. (2013) on the same test of are also complied. Figure 5.6 depicts the comparison in these three studies.

When domestic waste plastic of dosage 0.5% by weight of cement was added in M20 grade concrete, an increase of 0.68 % and 5.12% in cube compressive strength in 7 days and 28 days respectively was noticed when compared results with plain concrete. Also, an increase of 1.63% and 2.45% was noticed in split tensile strength in 7 days and 28 days respectively in comparison to its results on plain concrete.

When glass fibers of 0.1% by volume fraction of concrete was added in M20 grade concrete, an increase of 8.95% and 11.16% in cube compressive strength in 7 days and 28 days was found respectively when compared with plain concrete. Also, an increase of 6.85% and 12.73% was observed in split tensile strength in 7 days and 28 days respectively in comparison to its results with plain concrete in the same study.

In the present study, by the addition of polypropylene graded fibrillated synthetic fiber to concrete, maximum increases in the cube compressive strength of concrete in 7 days and 28 days is found out to be 9.45% and 11.78% respectively @ 0.2% fiber content. Also, maximum increases in the cylinder split tensile strength of concrete in 7 days and 28 days is found out to be 18.01% and 9.12% respectively @ 0.2% fiber content, maximum increases in the cylinder split tensile strength of concrete in 28 days is found out to be 9.12% @ 0.2% fiber content.

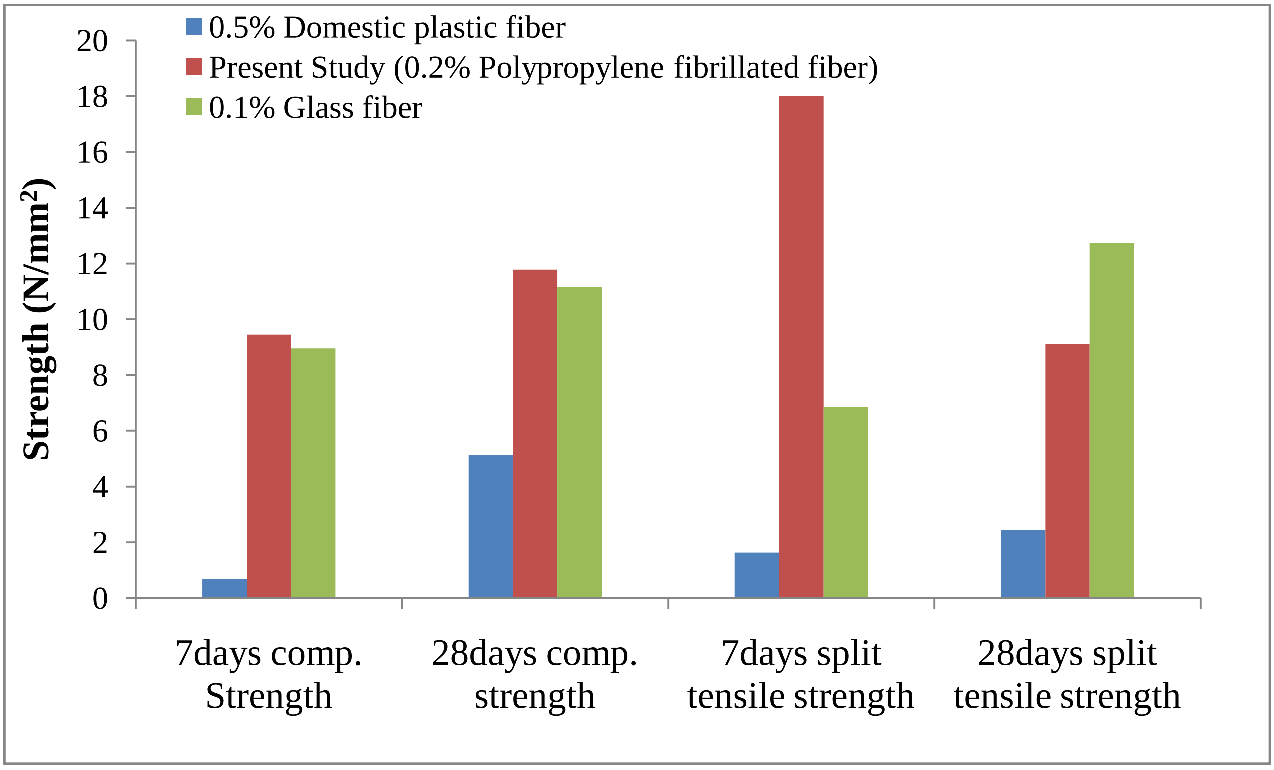


Figure 5.6: Comparison of different types of fibers on the basis of mechanical properties of concrete

5.4 Conclusions

As our objective was to observe various changes in the properties of M20 concrete when different percentage of fiber are added to it and to find out its optimum percentage. Various experiments are done and results are analysed, compared and discussed.

The following conclusions are presented based on experimental results from the present and previous studies investigation. By the addition of polypropylene graded fibrillated synthetic fiber to concrete, the slump value decreases with the increase in fiber dosages. It is clearly visible from the above bar chart that using 0.2% polypropylene fibrillated fiber in M20 concrete shows significant increase in compressive and split tensile strength and is better than other two fibers. Only in case of 28 days split tensile strength, 0.1% glass fiber shows the maximum strength. But if we overall conclude, then we can consider polypropylene fiber as best among the three.

So, we can conclude that our study is successful as we have drawn many conclusions and fulfilled our objective.

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APPENDIX-A

Slump Test Results

S.No.	SPECIMEN TYPE	SLUMP VALUE	TYPE OF SLUMP
1.a) b)	Fresh Plain Concrete	60 mm 50 mm 40 mm	True Slump
2.a) b)	Fresh Concrete Containing 0.1% Fiber	40 mm 30 mm 20 mm	True Slump
3.a) b)	Fresh Concrete Containing 0.2% Fiber	20 mm 20 mm 20 mm	True Slump
4.a) b)	Fresh Concrete Containing 0.3% Fiber	0 0 0	True Slump

APPENDIX-B

Results of 7 days Cube Compressive Strength Test

Grade of Concrete	% of fiber used	Sample No.	Load (kN)	Compressive Strength(N/mm^2)
M20	0%	1	525	23.33
		2	510	22.66
		3	500	22.22
	0.1%	1	550	24.44
		2	545	24.22
		3	535	23.77
	0.2%	1	555	24.67
		2	560	24.89
		3	565	25.11
	0.3%	1	540	24
		2	530	23.56
		3	535	23.77

Results of 28 days Cube Compressive Strength

Grade of Concrete	% of fiber used	Sample No.	Load (kN)	Compressive Strength(N/mm^2)
M20	0%	1	755	33.56
		2	745	33.11
		3	740	32.89
	0.1%	1	805	35.78
		2	785	34.89
		3	765	34.0
	0.2%	1	850	37.78
		2	820	36.44
		3	835	37.11
	0.3%	1	800	35.56
		2	810	36.0
		3	785	34.89

APPENDIX-C

Results of 7 days Cylinder Split Tensile Strength Test

Grade of Concrete	% of fiber used	Sample No.	Load (kN)	Split Tensile Strength(N/mm^2)
M20	0%	1	75	1.1
		2	75	1.1
		3	80	1.13
	0.1%	1	85	1.2
		2	85	1.2
		3	90	1.27
	0.2%	1	90	1.27
		2	95	1.33
		3	95	1.33
	0.3%	1	85	1.2
		2	85	1.2
		3	90	1.27

Results of 28 days Cylinder Split Tensile Strength Test

Grade of Concrete	% of fiber used	Sample No.	Load (kN)	Split Tensile Strength(N/mm^2)
M20	0%	1	205	2.90
		2	200	2.83
		3	200	2.83
	0.1%	1	210	2.97
		2	210	2.97
		3	215	3.00
	0.2%	1	225	3.18
		2	215	3.04
		3	220	3.11
	0.3%	1	210	2.97
		2	205	2.90
		3	215	3.04