Effect of wheat straw ash and Addition of steel fiber and PPF on properties of concrete

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Abstract

Concrete is the foremost and most widely construction material around the globe. Its worldwide production is about 5.3 billion cubic meters per annum, making it the second most utilized material on earth after water. The cement industry is one of the main producers of carbon dioxide and is found to be 8 % of the world's carbon dioxide emissions. Wheat straw is the byproduct or leftover once wheat is harvested so in our research we will replace the wheat straw ash (WSA) as a partial replacement in place of cement in concrete along with steel fiber (SF) and polypropylene fibers (PPF). This research mainly focused on the concrete's fresh, microstructural, mechanical, and durability performance. For this purpose, five M20 grade concrete mixes were prepared, with varying percentages (0, 0.20, 0.25, and 0.30) of SF and PPF with a constant 10% WSA. The mechanical performance was evaluated based on compressive and split tensile strength, and durability through water absorption while microstructural properties were assessed through Scanning electron microscopy (SEM) and Fourier transform infrared (FTIR) spectroscopy. The result revealed that mechanical, durability and microstructural properties show optimal results on 0.25% replacement of SF, PPF, and with combination of both replacements.

UNDERTAKING

Undertaking

Use the following undertaking as it is.
I certify that the research work titled "*Effect of wheat straw ash and Addition of steel fiber and PPF on properties of concrete*" is my work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/referred.

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Sustainable Development Goals

(Please tick the relevant SDG(s) linked with FYDP)

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	SDG 9	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	SDG 11	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

<table>
<tr><th colspan="4">Range of Complex Problem Solving</th></tr>
<tr><td></td><td>Attribute</td><td>Complex Problem</td><td></td></tr>
<tr><td>1</td><td>Range of conflicting requirements</td><td>Involve wide-ranging or conflicting technical, engineering and other issues.</td><td></td></tr>
<tr><td>2</td><td>Depth of analysis required</td><td>Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.</td><td></td></tr>
<tr><td>3</td><td>Depth of knowledge required</td><td>Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.</td><td></td></tr>
<tr><td>4</td><td>Familiarity of issues</td><td>Involve infrequently encountered issues</td><td></td></tr>
<tr><td>5</td><td>Extent of applicable codes</td><td>Are outside problems encompassed by standards and codes of practice for professional engineering.</td><td></td></tr>
<tr><td>6</td><td>Extent of stakeholder involvement and level of conflicting requirements</td><td>Involve diverse groups of stakeholders with widely varying needs.</td><td></td></tr>
<tr><td>7</td><td>Consequences</td><td>Have significant consequences in a range of contexts.</td><td></td></tr>
<tr><td>8</td><td>Interdependence</td><td>Are high level problems including many component parts or sub-problems</td><td></td></tr>
<tr><th colspan="4">Range of Complex Problem Activities</th></tr>
<tr><td></td><td>Attribute</td><td>Complex Activities</td><td></td></tr>
<tr><td>1</td><td>Range of resources</td><td>Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).</td><td></td></tr>
<tr><td>2</td><td>Level of interaction</td><td>Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.</td><td></td></tr>
<tr><td>3</td><td>Innovation</td><td>Involve creative use of engineering principles and research-based knowledge in novel ways.</td><td></td></tr>
<tr><td>4</td><td>Consequences to society and the environment</td><td>Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.</td><td></td></tr>
<tr><td>5</td><td>Familiarity</td><td>Can extend beyond previous experiences by applying principles-based approaches.</td><td></td></tr>
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ACKNOWLEDGEMENT

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Chapter I

1 Introduction

1.1 Background and Introduction of FRC:

Concrete is the most major used material for construction which has a lot of engrossing properties like stiffness, durability, and top compressive strength below regular environmental factors. At the same time, concrete is good while brittle and sick in tension. Plain cement concrete has two paucities, inadequate tensile strength, and an intermittent strain value at fracture strength. Generally reinforced cement concrete includes continuous distorted steel bars or high tensional wires. The benefit of reinforced cement concrete and high tensional wires for pre-stressing technology use fiber reinforcement as high tensile strength has support to overcome the inability of concrete in tension, even so, the concrete has the best compressive strength. [1]

To get the better of defects of conventional concrete including low tensile has originated in recent years. The ductility of (FRC) depends on the capacity of fibers to bridge fracture at a high grade of strain. The inclusion of polypropylene fiber reduces the unit weight of concrete and improves its strength. Satisfactory concrete should have high strength and minimum permeability. The addition of polypropylene fiber concrete is less permeable and achieves good tensile and compressive [2]

Regular plain-concrete (PC) takes to high design thickness when it is used in applications where a higher level of compressive strength is essential. Therefore, to keep down the depletion of natural resources and to avoid massive design thickness, it is primary to upgrade the compressive strength of conventional concrete (PC) by using supportive materials i.e. steel re-bars, and fibers. Different varieties of fibers are being applied in the construction industry including steel, glass, polypropylene, carbon, basalt fibers, cork fiber, cardboard fibers, etc. and properties of concretes with these kinds of fibers have been assessed widely. Because of excessive tensile strength and elastic modulus, fiber reinforcement can improve the magnitude of the binder matrix of concrete to contain the tensile or compressive cracks that conclusively boost the compressive capacity of the material.[3]. Producing cement has significant positive and negative impacts at a local level. On the positive side, the cement industry may create employment and business opportunities for local people, particularly in remote locations in developing countries where there are few other opportunities for economic development. Negative impacts include disturbance to the landscape, dust, and noise, and disruption to local biodiversity from quarrying limestone (the raw material for cement). Cement manufacturing contributes greenhouse gases directly through the production of carbon dioxide when calcium carbonate is heated (producing lime and carbon dioxide) and indirectly through the use of energy, particularly if the energy is sourced from fossil fuels. The cement industry produces about 8% of global man-made CO2 emissions, of which 50% is from the chemical process and 40% from burning fuel. The amount of CO2 emitted by the cement industry is nearly 900kg of CO2 for every 1000kg of cement produced. Wheat straw ash is found to be superior to other supplementary materials like slag, silica fume, and fly ash. Unlike other industrial by-products wheat straw ash has to be produced out of raw agricultural waste, Ash

Due to its high pozzolanic activity, both the strength and durability of concrete are enriched so we are going to use this by-product to know the behavior of concrete under wheat straw ash instead of using cement which has many worse effects on the environment when it is produced and also we want to be in safe side so we are also using steel fiber to have maintain strength and prevent from all worse effect.

1.2 Introduction of Fibers Used in FRC:

Some types of fibers have been used in concrete. Several used fibers are synthetic, natural, metal, and steel fibers which are discussed below.

- Steel fiber
- Polypropylene fiber

1.2.1 Steel Fibers

Steel Fiber-Reinforced Concrete (SFRC) is a synthesized material that unites a cementitious matrix besides discontinuous reinforcement containing steel-fibers casually distributed in the matrix. SFRC is progressively being adopted for the fabrication of in-situ and prefabricated concrete structures as, auxiliary reinforcement for limited load cases, partial substitution of traditional reinforcement, and entire replacement of regular reinforcement in elements in overall compression. The usage of steel fibers for structural applications, as well as a partial or total replacement of traditional reinforcement bars, has become an easy way for the construction of concrete infrastructure. Even so, the total replacement of traditional steel reinforcement is controversial, mainly when the long-term durability of SFRC under severe manifesting conditions is addressed.[4]

figure 1 1 Steel fiber

1.2.2 Polypropylene Fiber:

The primary cause for adding short discrete polypropylene fiber into a cement matrix is to minimize cracking in the elastic range, stop plastic settlement cracking, control the plastic shrinkage cracking, control water migration in concrete and reduce bleeding, improve the tensile strength, increase compressive properties of concrete and improve deformation ability and the toughness of the resultant composite, improve abrasion resistance significantly and to batter fire resistances of concrete. Increasing fatigue performance is one of the main reasons for the immense use of PPFRC in pavements, bridge decks, machine foundations, and offshore structures where the composite is subjected to cyclically changing loads throughout its lifetime.[5]

figure 1 2 Polypropylene fibers

1.3 Problem Statement:

The cement industry is one of the main producers of carbon dioxide and is found to be 8 percent of the world's carbon dioxide emissions so partial replacement of cement with wheat straw ash would be done to know the effect of binding in concrete instead of binding through cement.

Tensile strength is increased commonly by steel bar reinforcement but as we know the difficulties being faced due to it such as consumption of field area, heavy weight, skilled labor requirement, etc. are also factors to be considered so steel fiber is the best option to use for tensile strength increment.

1.4 Justification of the Research:

Previous researchers have also studied the impact of different types of fibers i.e. steel fibers, PP fibers bagasse fiber, coconut fiber, coir fiber, banana peel fiber, banana stem fiber, straw fiber, carbon Nanofibers, etc. on the different properties of conventional as well as lightweight heavy weight and high strength concrete. Some researchers also have studied the combined effects of different fibers on the mechanical and physical parameters of concrete. Some researchers have also worked on the combination of additives and fibers as both addition and partial replacement of cement fine aggregate and coarse aggregate. As far as the latest literature is concerned we have found a little work on partially replacing cement with WSA and reinforcing the concrete with steel fiber. Steel fiber is made of iron and steel alloy which has good compressive properties.

This research is based on the study of the effects of replacing cement with WSA on the mechanical physical as well and durability properties of steel fiber-reinforced concrete. This wheat straw ash is a waste material having pozzolanic activities and steel fiber helps in improving the bending characteristics of concrete.

1.5 Research Goals:

The main goals of this research study are explained below.

1.5.1 Aim of the Research:

The research aims to develop heavyweight concrete by partial replacement of cement with wheat straw ash and using steel fiber as reinforcement in concrete. The research focuses on the improvement of strength parameters and durability properties of fiber-reinforced concrete. The other area of interest is the selection of the optimum percentage of wheat straw ash which gives the best possible results of mechanical physical and durability properties.

1.5.2 Research Objectives:

- To improve durability performance such as waterproofing or making low permeable concrete.
- To improve mechanical properties such as compressive, and tensile strength.
- To check various percentages to achieve the optimal mix percentage.

1.6 Organization of the Research Study:

This research study mainly consists of 5 major chapters. Each chapter includes distinctive headings and subheadings to portray the ideas of the author. The organization or arrangement of the research is given below.

The thesis contains the following chapters:

1.6.1 Chapter 1 (Introduction):

In this chapter introduction of the research, the topic is explained, and other outlines include the problem statement research goals, scope, aims, and objectives of this research.

1.6.2 Chapter 2 (Literature Review):

This chapter discusses previous research studies carried out by academic researchers and the findings of those research studies on this topic.

1.6.3 Chapter 3 (Methodology):

In this chapter the overall procedures and methods which are carried out to complete this study are discussed, this chapter includes a flow chart containing all the steps required to carry out the research and major data collection sources of the research data to perform a quantitative analysis.

1.6.4 Chapter 4 (Result and Discussions):

This chapter contains all the results of the collected data, analysis of the data, the visualization of the data collected, and all the graphs required to justify the aims objectives, and main research goals, and it contains the discussion about the results obtained and justified by the literature.

1.6.5 Chapter 5 (Conclusions and Recommendations):

This chapter covers the overall summary of the results and what is concluded from the research. The recommendations for future researchers are also discussed in this chapter.

1.6.6 Chapter 6 (References):

This chapter includes references from previous literature to justify this research study.

Chapter II

2 Literature Review

2.1 Preface of the Chapter:

In this chapter of the study, the construction of this research is discussed and illustrated, as well as the previous research on High-strength concrete and the effect of different additives, polymers, and fibers on the mechanical, physical, and durability properties of binding wire reinforced. In this chapter, the optimum percentages of different fibers, the reasons behind the improved properties, and different mix designs are also discussed. The current state of scientific knowledge concerning the topic of this investigation is also included in this section.

2.2 Previous Researches:

Concrete is a widely utilized construction material around the world, and its durability is currently a major problem. One such admixture is rice husk ash (WSA). The purpose of this study is to investigate the durability of Normal Concrete (NC) and Steel Fiber wheat straw ash Concrete (SFWSAC). M20-grade concrete with standard constituents was designed and used as a reference. WSA was utilized to partially replace Ordinary Portland Cement (OPC). The replacement amounts under consideration were 10, 20, and 25%. It was discovered that the workability of concrete deteriorated as the replacement amount increased. NC. Cube compressive strength was measured after 28 days. Water-cured SFWSAC has a higher compressive strength than NC. For all exposure times, the compressive strength of both NC and SFWSAC was observed to decrease in acidic solution; however, the loss was smaller in the case of SFRHAC. The XRD study was performed to determine the influence of nitric acid on concrete ingredients. In SFWSAC samples, the higher peaks of Calcium Silicate Hydrate (C-S-H) are found.**[9]**

In this research steel and PP fibers were used in high-strength concrete. A total of 12 batches were made to understand the individual and combined effect of both fibers on HSC with 10% silica fume in each batch. Mechanical properties like compressive strength, splitting tensile strength, and flexural strength were evaluated. Durability properties such as electrical resistivity and water absorption were also evaluated. The result of compressive strength indicates that the use of SCMs increased compressive strength. The results indicate that the compressive strength of concrete increases from 5% to 15% as a result of the addition of polypropylene fibers to the mix. It was also observed that the effect of steel fibers was more significant than that of polypropylene fibers in the improvement of compressive strength. This can be attributed to the higher strength and elastic modulus of steel fibers compared to those of polypropylene fibers, which result in their higher efficiency in bridging macro-cracks and consequently increasing the compressive strength. the best-performing mix was the one with 0.25 % steel fiber and PP fiber, which attained a 28-day compressive strength of 37.51 MPa. The results of the hybrid fiber-reinforced concrete show that the substitution of steel fiber with PP fiber results in a lower mechanical strength. The higher tensile strength and modulus of elasticity of steel fibers are the two main factors that contribute toward the better performance of steel fiber-reinforced concretes. Moreover, the addition of steel fibers significantly decreases the electrical resistivity of concrete due to the conductivity characteristics of the fibers **[10]**. Pulverized fly ash (FA), pulverized granulated blast furnace slag (PS), and silica fume (SF) were quantitatively examined with the addition of Portland cement in this study (PC). PC was replaced at defined ratios with FA or PS. The aggregates in the mixtures were basalt and quartz powder. The specimens were cured using three distinct procedures (standard, autoclave, and steam). The results of the tests show that high-volume mineral admixtures can produce high-strength concrete. These mixes have a compressive strength of more than 170 MPa. With some changes, it appears that these mixes can also be utilized to produce reactive powder concrete (RPC) **[11]**. Aside from its remarkable mechanical capabilities, scanning electronic microscope (SEM) has a scanning electronic microscope. In this, the electron interacts with the simple therefore producing various signals that can be used to obtain about the surface topography and composition**.[12].** Polypropylene fiber is a kind of polymer material with lightweight, high strength, and corrosion resistance. The crack resistance of concrete can be improved by adding PPFs.**[13].**

The usage of supplemental cementitious materials (SCMs) has grown in recent years due to the carbon footprint associated with cement manufacture, which accounts for 10% of total global CO2 gas emissions. This contributes to global warming, and the exponential increase in demand for concrete construction has resulted in natural resource depletion. Furthermore, as cities become more densely populated, vast amounts of agro-industrially processed trash are generated and thrown into landfills, resulting in major land scarcity, environmental difficulties, and pollution. As a result, it is vital to cut CO2 emissions by decreasing our reliance on cement as a binder and generating eco-friendly concrete utilizing alternative binders derived from agro-industrial waste materials. Wheat straw ash (WSA) is used as the SCM in this study, with polypropylene (PP) fibers reinforcing it. The cement content is replaced with 10 to 30 % WSA with a 5% increment, with PP fiber reinforcement ranging from 0.20 to 0.30 percent. Based on the results, it can be seen that concrete containing 10 % WSA and reinforced with 0.25 percent PP fibers performed better than the specimen lacking SCM. However, increasing the WSA percentage further reduced concrete strength, which could not be restored totally with PP fiber reinforcement, though concrete with greater (20%) WSA reinforced with PP fibers could be used for non-structural and low-cost construction. **[14].**

In recent years, one of the primary focuses of waste management systems has been waste material utilization. Because of its technological, economic, and environmental benefits, advancements in cement and concrete technology toward the creation of sustainable concrete utilizing waste resources and cellulosic fiber are progressively gaining favor. This study looked into the usage of a natural fiber known as steel fiber and wheat straw ash (WSA) from agricultural waste to create a bio-fibrous concrete with improved impact resistance and strength capabilities. Four mixes with varied percentages of WSA from 0% to 15% at 5% intervals were utilized as a foundation for comparison against four other mixes created with 12 mm length fiber of 0.5 percent volume fraction and WSA of 0% to 15% as supplemental cementing material. The impact resistance strength and energy absorption of the WSA-based steel fibrous concrete were determined using the drop weight impact test method. The use of steel fiber reduced the slump values. The compressive strength of the fibrous concrete mixtures including WSA rose significantly with age, and the values obtained were higher than the mix with OPC alone. The interaction of steel fibers with WSA results in high tensile strength, and impact resistance, enhancing concrete ductility with higher energy absorption and improved fracture distribution. The study found that steel Fiber (SF) at 5% and 10% wheat straw ash (WSA) produced compressive strength, splitting tensile strength, and energy absorption values that were 12 percent, 26.3 percent, 30.8 percent, and 3.9 percent higher than the control. Steel fiber and wheat straw ash can be employed as building materials in the creation of sustainable concrete, according to the findings.**[15]**

Chapter III

3 Methodology and Materials

3.1 Introduction of Chapter:

This chapter discusses the specifications of material used, casting schedule, mix proportions, methodology, procedure, and code references of tests performed on concrete and working criteria adopted to achieve the aforementioned objectives summarized.

3.2 Materials:

Following is the detail of materials used in the experimental program.

3.2.1 Cement:

Type I cement is used that is available in the nearby local market branded as Fauji cement has been used in this project study. Different physical tests are performed on the cement to ascertain its quality before use. The cement had a fineness of 3176 /gm, an initial setting time of 48 minutes, a final setting time of 398 minutes, a consistency of 28%, and a specific gravity of 3.02. No expansion there was found in the soundness test. The Compressive strength of the mortar cube was 29.31 MPa for 28 days.

3.2.2 Fine Aggregate:

Lawrancepure sand is used that is available in the nearby local markets as fine aggregates. The Fineness modulus of sand is 2.77, specific gravity of 2.70, and water absorption of 1.23%. The results of the sieve analysis performed on the fine aggregates as per ASTM C136-06 have been shown in Table 3.1, and a graph of the particle size distribution of fine aggregates is given in Fig.

Table 3 1 Sieve analysis results of fine aggregates

BS (mm Or µm)	**ASTM**	**Mass retained (g.)**	**Percentage Retained**	**Cumulative percentage passing**	**Cumulative percentage retained**
9.5 mm		0	0	100	0
4.75 mm	# 4	23	2.3	97.7	2.3
2.36 mm	# 8	91	9.1	88.6	11.4
1.18 mm	# 16	155	15.5	73.1	26.9
600 µm	# 30	257	25.7	47.4	52.6
300 µm	# 50	340	34	13.4	86.6
150 µm	# 100	97	9.7	3.7	96.3
	pan	37	3.7	0	-
	Total	1000		Total	276.1
Fineness modulus = 2.77					

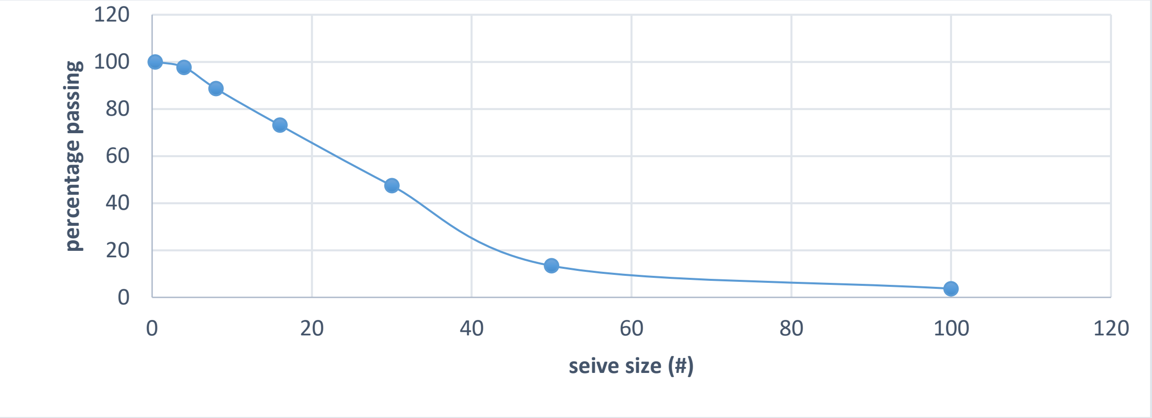


Figure 3 1 Particle size distribution of fine aggregates

3.2.3 Coarse Aggregates:

Margalla crush conforming B.S. 882 1992 was used as coarse aggregate. Two different-sized coarse aggregates were mixed in the following percentage.

- Coarse aggregate passing from 20 mm sieve (Type-I)
- Coarse aggregate retained on from 9.5 mm sieve (Type-II)

The coarse aggregate had a specific gravity of 2.71 for Type-I and 2.73 for Type-II and water absorption was found to be 0.74% for both types. Sieve analysis results of coarse aggregates are shown in the table.

Table 3 2 Sieve analysis results of coarse aggregates

BS (mm)	ASTM	Percentage Retained	Cumulative percentage passing	Cumulative percentage retained
20		12.4	87.6	12.4
12.5		36	51.6	48.4
9.5		42.5	9.1	90.9
	Pan	9.1	0	9.1

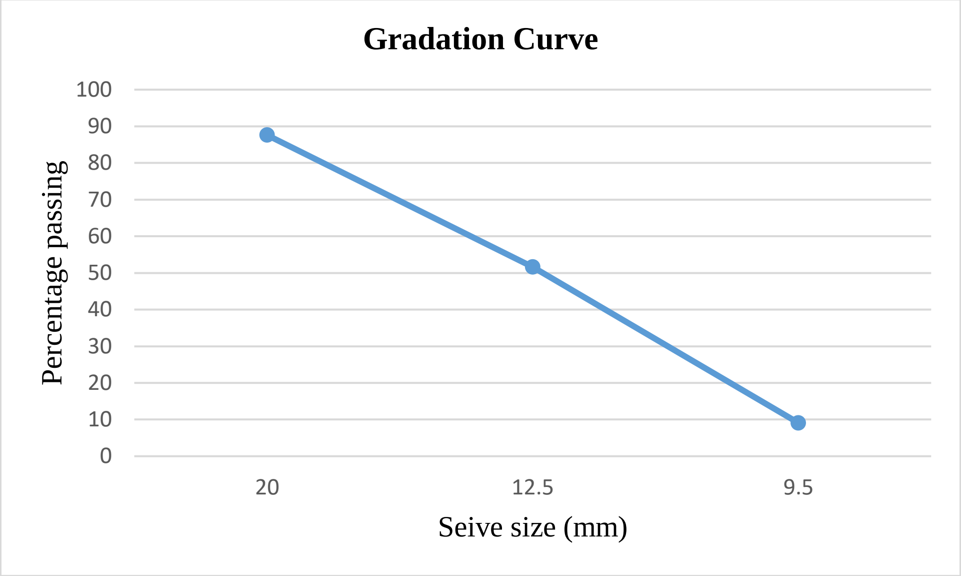


Figure 3 2 Particle size distribution of coarse aggregates

3.3 Steel fiber and PP fiber:

Locally available steel fiber and PP fiber were used.

3.4 Water:

Normal tap water available in the concrete laboratory of the Swedish College of Engineering and Technology Wah Cantt, good for drinking, was used in this research. The pH value of SCET water is 7 and the limitations of max allowable limit by WHO guidelines is 6.5 to 7.5.

3.5 Casting Schedule:

3.5.1 Mix Design:

To study the properties of building wire reinforced concrete, different percentages of building wire are added by the weight of the concrete. For the mix1 sample, we go for M20 grade concrete in which there will be no steel fibers, PP fiber, and wheat straw ash. The complete mix design can be seen in the Table below. and wheat straw ash was added instead of cement by 10% For destructive testing, compressive and split tensile strength at 28 days were determined and for non-destructive testing, water absorption test of concrete will be considered at 28 days. The water-to-cement ratio will remain the same for the study at 0.55.

Table 3 3 Detail of mixes studied

Mix ID	**Mix Proportion**						
	Cement (%)	**Aggregate (%)**	**Polypropylene fiber (%)**	**Steel fiber**	**Wheat straw ash (%)**	**Water cement ratio**	**admix superplasticizer ratio (%)**
M1	**100**	**100**	**0**	**0**	**0**	**0.55**	**1**
M2	**95**	**100**	**0**	**0**	**5**	**0.55**	**1**
M3	**90**	**100**	**0**	**0**	**10**	**0.55**	**1**
M4	**85**	**100**	**0**	**0**	**15**	**0.55**	**1**
M5	**20**	**100**	**0**	**0**	**20**	**0.55**	**1**

3.5.2 Casting of test samples:

26 beams for compressive strength and split for 28 days for 5 mixes. As same 26 cylinders were cast for split tensile strength test for 28 days for each of the 5 mixes. As same 26 cubes were cast for water absorption test for each of the 5 mixes for 28 days

Table 3 4 Casting schedule and details of test specimens

Test	Curing	No of samples
Compressive	28	26
Tensile	28	26
Water absorption	28	26
Microstructure	28	26

3.6 Test performed:

The following tests were performed

3.6.1 Tests on cement:

3.6.1.1 Consistency test:

A consistency test was executed on cement according to EN 196-3 1987 specifications. Took 300g of cement and put it in a basin or tray to use for this. Now, assuming that water has a standard consistency of 26%, add the same amount of water to the cement and stir. Within 3 to 5 minutes, properly combine the paste. Gauging time is the length of time needed to create a homogeneous mixture after adding water. Using a trowel, remove any surplus paste that remained on the Vicat mold after properly filling it with paste. After that, set the VICAT mold on a glass plate and check to make sure the plunger is lightly touching the mold's surface. Let the Plunger dip into the test mold after releasing it. Take note of the plunger's penetration from the mold's bottom as shown on the scale. Repeat the test adding water in various amounts until the Vicat instrument scale registers a reading of between 5-7mm. 28 percent of cement was determined to be consistent.

3.6.1.2 Setting time test:

Setting time test was executed on cement according to EN 196-3 1987 specifications. Take 400g of cement and put it into a bowl or tray. Add some water now. As soon as the water is introduced to the cement, start the timer. Considered is the water with an amount of 0.85 times P (where P is the standard cement consistency). Now pour the mixture into the Vicat mold. A trowel is used to remove any remaining extra paste from the Vicat mold. The VICAT mold should then be placed on a non-porous plate (glass plate) and the plunger should just touch the surface of the VICAT mold. Let the Plunger dip into the test mold after releasing it. Take note of the plunger's penetration from the mold's bottom as shown on the scale. Until the plunger stops penetrating 5 mm from the bottom of the mold, repeat the process at various points on the mold. The initial setting time of cement is the interval from the time water is poured into the cement until the needle cannot pierce the mold by 5 mm when determined from the bottom of the mold.

The needle (plunger) should now be swapped out by one with a circular connector. When the connector fails to leave an impression on the test mold surface after gently pressing the needle against it, the cement is considered to have reached its final setting point. The ultimate setting time of cement is measured from the time the water to the cement until the needle leaves a mark on the surface of the mold while the connector does not**.** The cement obtained a start-setting time of 61 minutes, and an end-setting time of 432 minutes.

3.6.1.3 Compressive strength test:

This test was performed according to ASTM C109/C109M **specifications.** In this mortar test, a 1:1.5:3 cement sand and aggregate mortar was used. The water-cement ratio used was 0.55. After this 102 mm (4 in) cubes were cast, de-mold after 24 hours, and further cured in water until tested in a wet surface condition. After proper curing, test samples were tested for compressive strength test on a pre-defined schedule. Compressive strength was then calculated as the average of 3 cubes at each age.

3.6.2 Test on concrete:

3.6.2.1 Compressive strength test (ASTM C39)

26 concrete cubes of 4-inch diameter and 4-inch length were cast for each of the 5 mixes for 28 days' compressive strength, and 26 cylinders were tested for 28 days after curing in water for durability purposes. The test was performed according to BS 1881:1970 specifications. In this test concrete having the ratio of 1:1.5:3 specified water-cement ratio and specified percentage of wheat straw ash and steel fiber and PP fiber was added in cubes 4-inch diameter and 4-inch length. The filling was done in 3 layers, and each layer was compacted by 25 strokes of a 5 mm (1 in) square rod. Ramming continued until sufficient compaction was achieved. Then the top surface of the mixes was finished utilizing a trowel, these cubes were stored undistributed for 24 hours at a temperature of 18 to 22 degrees centigrade and relative humidity of 90 percent. At the end of these 24 hours, the molds were stripped and cubes were placed in the water for further curing. After curing for a specified period the cubes were tested for compressive strength at a pre-defined schedule. For the compression test, the cube was placed in the 37.51 MPA compression testing machine at right angles to the caste position, and the load was applied at a constant rate until the failure occurred. Then the compressive strength of the cube was calculated as the average of 4 cylinders. This complete procedure was repeated for all 5 mixes. The compressive strength of the cylinder was calculated using equation 3.1 as under:

$$\text{Compressive strength} = C = \frac{P}{A} \qquad (3.1)$$

Where:

- C = compressive strength, Mpa (psi)
- P = load at failure, N (psi)

Compressive strength was calculated as the average of 3 cubes at each age. This complete procedure was repeated for all 5 mixes.

Figure 3 3 Compressive testing machine

3.6.2.2 Split cylinder test (ASTM C496)

8 concrete cylinders 150 mm diameter and 300 mm length were cast for each of the 5 mixes, 4 cylinders were tested for 28 days after curing in water for durability purposes. The test was performed according to ASTM C496-71 specifications. In this test concrete having the ratio of 1:1.5:4 specified water-cement ratio and specified percentage of wheat straw ash and steel fiber and PP fiber was added in (150 mmΦ x 300 mm) steel cylinders' molds. The filling was done in 3 layers, and each layer was compacted by 25 strokes of a 5 mm (1 in) square rod. Ramming continued until sufficient compaction was achieved. Then the top surface of the mixes was finished employing a trowel, these cubes were stored undistributed for 24 hours at a temperature of 18 to 22 degrees centigrade and relative humidity of 90 percent. At the end of these 24 hours, the molds were stripped and cubes were placed in the water for further curing. After curing for a specified period the cylinders were tested for split tensile strength at a pre-defined schedule. For the split tensile test, ASTM C496-71 specifications were followed. The cylinder was placed horizontally

between the plates of the testing machine and the compressive load was applied increasingly at a constant rate until failure by indirect tension in the form of splitting along its vertical diameter took place, and the split cylinder strength of the cylinder was calculated using equation 3.2 as under:

$$\text{Split tensile strength} = T = \frac{2P}{\pi LD} \qquad (3.2)$$

Where:

- T = tensile strength, Mpa (psi)
- P = load at failure, N (psi)
- L = length of specimen = 6 in
- D = diameter of specimen = 12 in

Split cylinder strength was calculated as an average of 3 cylinders at each age. This complete procedure was repeated for all 4 mixes.

Figure 3 4 Split tensile strength test on cylinder

3.6.2.3 **Slump test** (ASTM C143)

A slump test was performed on all 4 concrete mixes to ascertain workability according to ASTM C143. For this test, 4 mixes with a mix ratio of 1:1.5:4. Specific water-cement ratios and different percentages of rice husk ash and building wire chopped content were prepared and tested for slump test cone. The filling was done in 3 layers, each layer was stamped with a standard 16mm diameter rod, and the top surface of the mix was leveled with the help of the tamping rod. After filling the mold, the cone was slowly lifted, and a decrease in the height of slumped concrete, which is known as slump, was noted to the nearest of 5 mm.

figure 3 5 slump test

3.6.2.4 Water Absorption (WA) (ASTM C1585):

A concrete's water absorption is used to indirectly assess the concrete's porosity. A concrete's water absorption is used to indirectly assess the concrete's porosity. The results of the water absorption test reveal the concrete's interior and exterior surfaces' respective water absorption rates (sorptivity). When just one face of the object is exposed to water during the test, the gain in mass of the concrete specimens as a result of water absorption is determined as a function of time.

Chapter IV

4 Results and Discussion

4.1 Pre-Face of the Chapter:

To evaluate the effects of using glass and polypropylene fibers on the different properties of concrete like compressive strength test split tensile strength test on hardened concrete, and slump test on fresh concrete were performed on 4 different concrete mixes at different curing days. In this chapter analysis of test results is discussed and summarized thoroughly.

4.2 Compressive strength

- Table 4.1 shows the results of compressive strength tests achieved on the test samples at 28 days of age. The values of compressive strength defined in the table are average values to be achieved by crushing 3 samples at specific ages. Table 4.2 shows the increase or decrease in the compressive strength of wheat straw ash and binding wire reinforced concrete with mention to control mix.

MIX ID	CEMENT (%)	AGGREGATE (%)	PPF (%)	WSA (%)	WATER CEMENT RATIO	ADMIXTURE	CS AT 28 DAYS
A1	100	100	0	0	0.55	1	26.32
A2	95	100	0	5	0.55	1	27.82
A3	90	100	0	10	0.55	1	29.31
A4	85	100	0	15	0.55	1	24.47
A5	80	100	0	20	0.55	1	23.68

Table 4 1 Compressive strength value with the addition of WSA

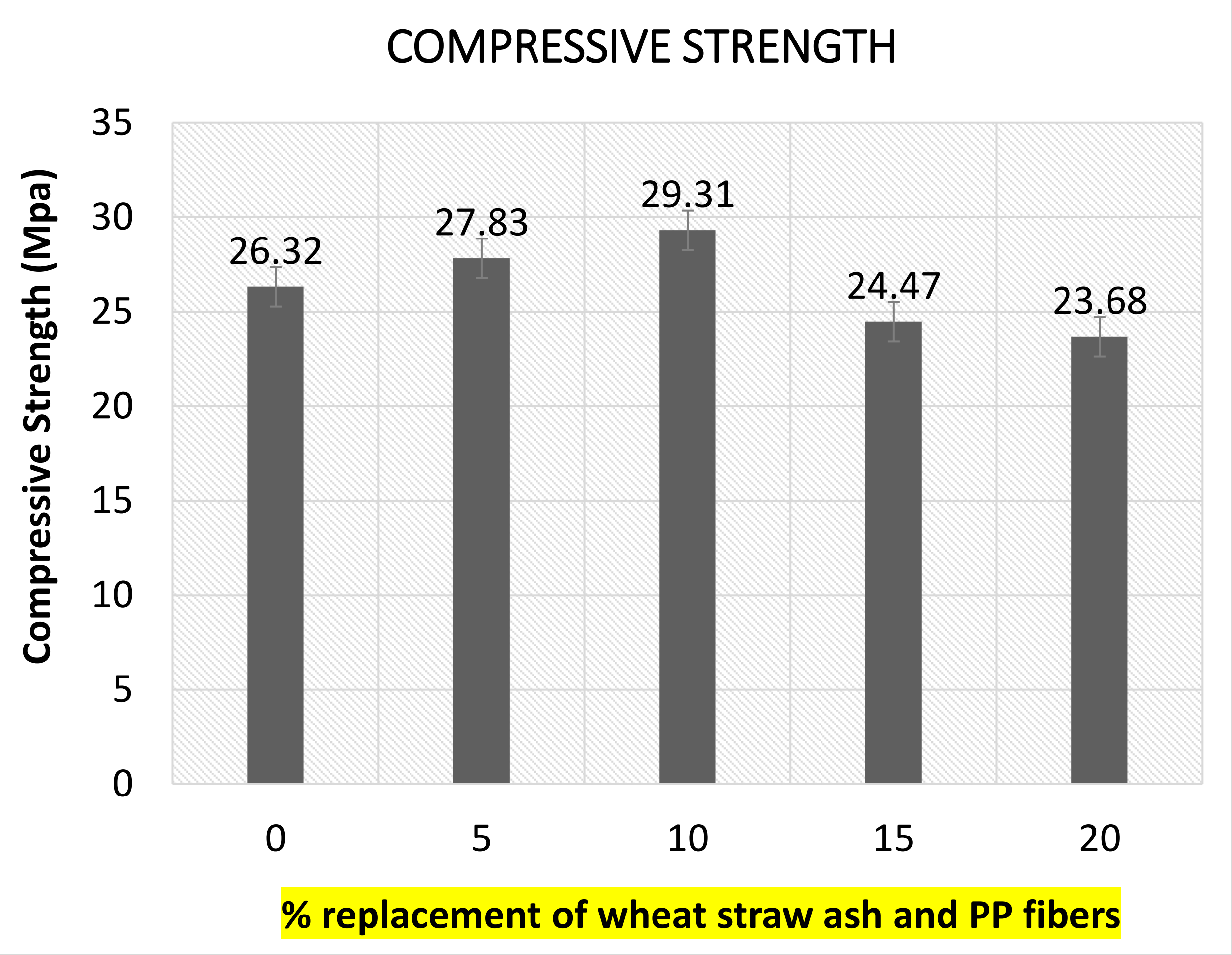


Figure 4 1 Compressive strength with the addition of WSA

It has been observed that the addition of wheat straw ash increases/decreases the compressive strength of concrete

4.1.2 Polypropylene (PP) fibers:

Polypropylene fibers are commonly added to concrete to improve its toughness and durability properties. While these fibers can help to reduce cracking in hardened concrete, they do not typically increase the compressive strength of the concrete. The primary benefit of adding polypropylene fibers to fresh concrete is to improve the bond between the concrete and reinforcement, which can help reduce the risk of cracking and reinforcing corrosion over time. The fibers also increase the tensile and flexural strength of the concrete, making it more resistant to bending and pulling forces. This bonding effect is achieved through the distribution of fibers throughout the concrete mix, which helps to create a more uniform and interlocking matrix of concrete particles. This results in concrete that is more resistant to cracking due to shrinkage stresses, as well as cracking caused by imposed loads or local impact. In summary, while polypropylene fibers can improve the toughness and durability of concrete, they are not typically used to increase the compressive strength of the material. Rather, their primary benefit is to increase the bond and reduce cracking in hardened concrete.

COMPRESSIVE STRENGTH AT 28 DAYS WITH polypropylene FIBER

Table 4 2 Compressive strength with the addition of PP fiber

MIX ID	CEMENT (%)	AGGREGATE (%)	PPF (%)	WSA (%)	WATER CEMENT RATIO	ADMIXTURE	CS AT 28 DAYS WITH PPF
A6	100	100	0.20	10	0.55	1	31.10
A7	90	100	0.25	10	0.55	1	32.56
A8	90	100	0.30	10	0.55	1	30.55

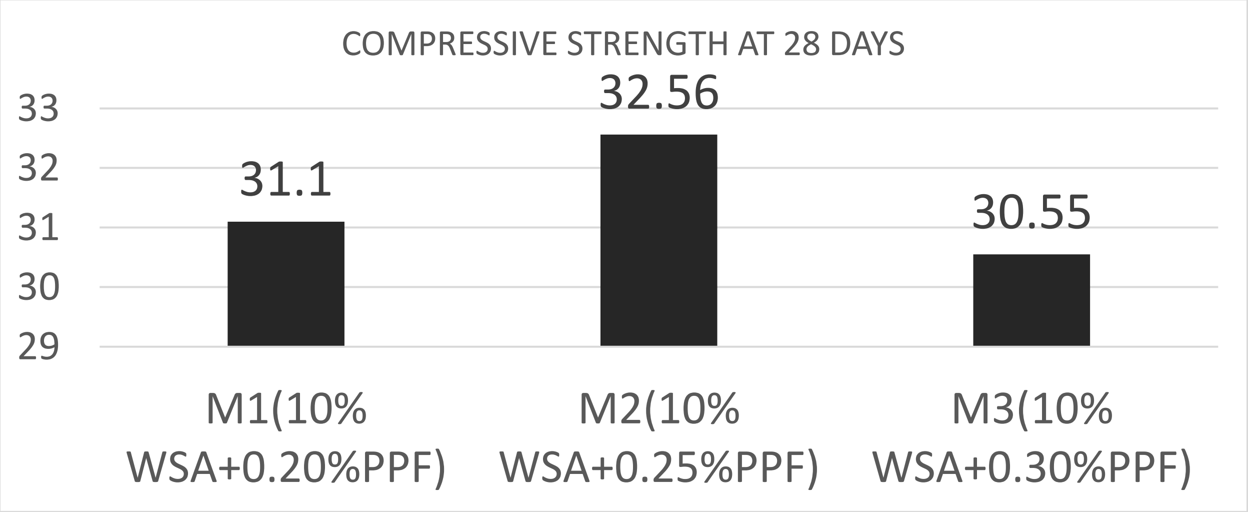


Figure 4 2compressive strength with the addition of PP fiber

4.3 STEEL FIBER

Hooks end steel fiber with a length of 12 mm is used in different percentages i.e. 0.20%,0.25%,0.30%, and the test performed and the values and given below.

Steel fibers mixed into the concrete can provide an alternative to the provision of conventional steel bars or welded fabric in some applications. The concept has been in existence for many years (the first patent was applied for in 1874), and it has been used in a limited range of applications: Among the first major uses was the patching of bomb craters in runways during World War II. However, it was during the 1970s that commercial use of this material began to gather momentum, particularly in Europe, Japan, and the USA.

Today, industrial floors and pavements are major applications for steel-fiber-reinforced concrete. In the United Kingdom, several million m2 of steel-fiber-reinforced slabs have been installed over the past ten years, both for ground-supported and pile-supported floors. Other major applications for fiber-reinforced concrete include external paved areas, sprayed concrete, composite slabs on steel decking, and precast elements

4.3.1 COMPRESSIVE STRENGTH WITH ADDITION OF STEEL FIBER

Table 4.3 Compressive strength with the addition of steel fiber

MIX ID	CEMENT (%)	AGGREGATE (%)	PP FIBER (%)	STEEL FIBER (%)	WHEAT STRAW ASH (%)	WATER CEMENT RATIO	ADMIXTURE SUPERPLASTICIZER (%)	CS WITH STEEL FIBER AT 28 DAYS
A9	90	100	0	0.20	10	0.55	1	34.55
A10	90	100	0	0.25	10	0.55	1	35.31
A11	90	100	0	0.30	10	0.55	1	33.01

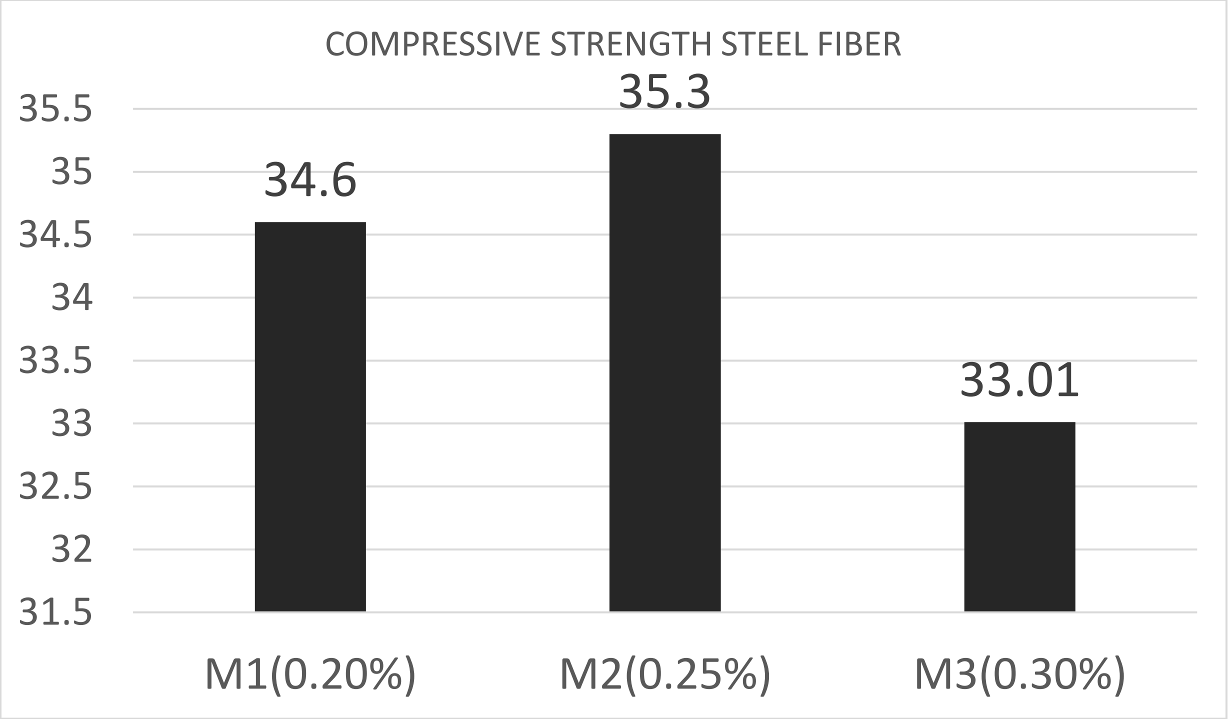


Figure 4.3 COMPRESSIVE STRENGTH WITH ADDITION OF STEEL FIBER

4.3.2 COMPRESSIVE STRENGTH WITH THE ADDITION OF PP FIBER STEEL FIBER

Table 4 4 Compressive strength with the addition of PP fiber and steel fiber

MIX ID	CEMENT (%)	AGGREGATE (%)	PP FIBER (%)	STEEL FIBER (%)	WHEAT STRAW ASH (%)	WATER CEMENT RATIO	ADMIXTURE SUPER PLASTICIZER (%)	COMPRESSIVE STRENGTH WITH PPF AND SF AT 28 DAYS
A12	90	100	0.20	0.20	10	0.55	1	37.01
A13	90	100	0.25	0.25	10	0.55	1	37.25
A14	90	100	0.30	0.30	10	0.55	1	36.33

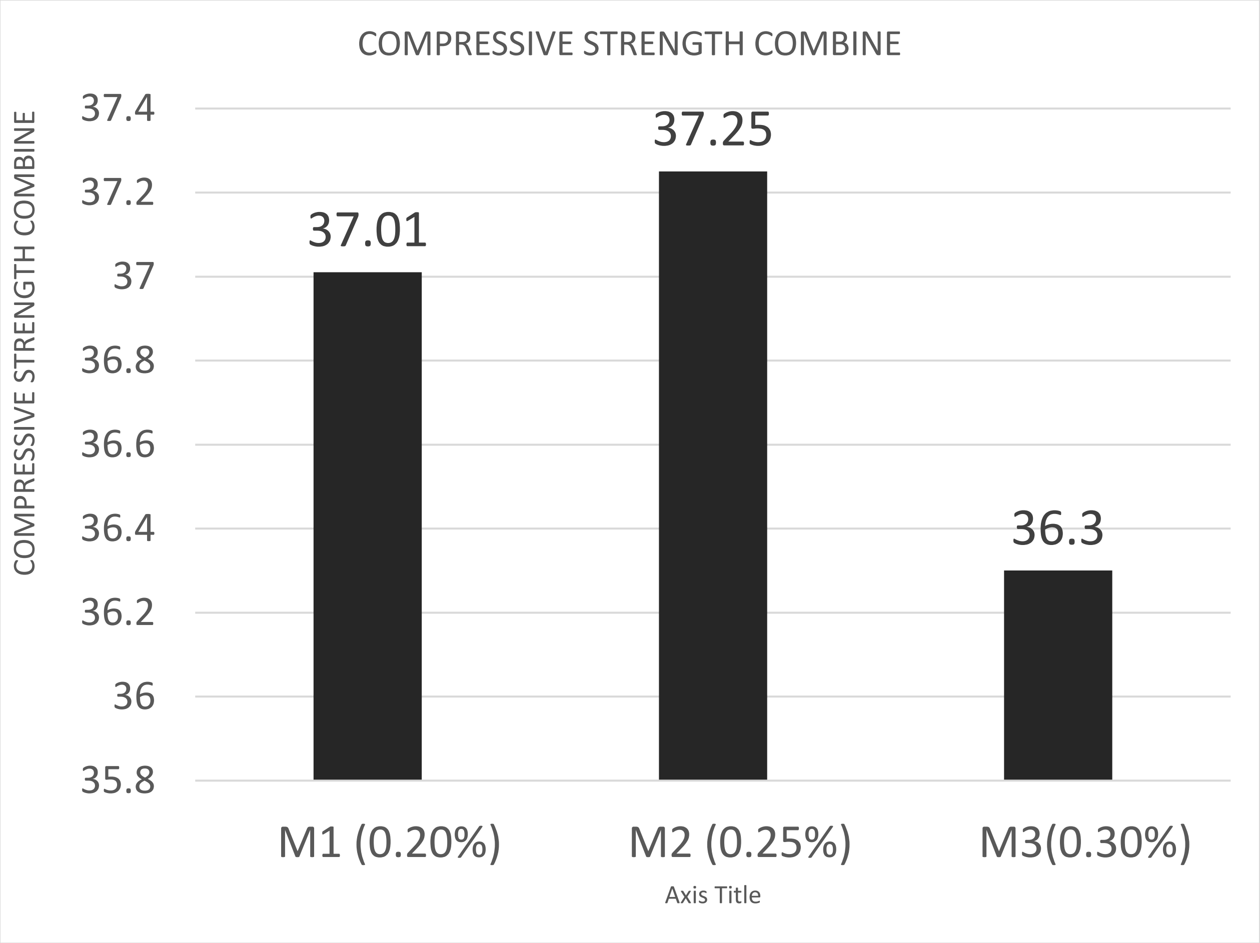


Figure 4 4 Compressive strength with the addition of PPF and SF

Graphical representation of results given in Table 4.1,4.2,4.3 shown in Figure 4.1,4.2,4.3 Figure specify variation in compressive strength after the addition of steel fibers, Polypropylene Fiber, and wheat straw ash as making a comparison to non-fiber concrete.

- The compressive strength of concrete increases concerning the control mix when we add steel fibers, Polypropylene Fiber, and wheat straw ash to concrete. This increase in strength shows in the ages of concrete we tested.

This research results show the change in strength by the addition of different ratios of steel fibers, Polypropylene Fiber, and wheat straw ash in concrete as compared to plain cement concrete. Table 4.1 4.2,4.2 represents an increase/decrease in compressive strength after the addition of steel fibers, Polypropylene Fiber, and wheat straw ash to make a comparison to the plain concrete without fibers. A graphical representation of the results given in Table 4.1 is shown in Figure 4.1

This has been observed that the addition of steel fibers, Polypropylene Fiber, and wheat straw ash increases the compressive strength of concrete. As we add steel fibers, Polypropylene Fiber, and wheat straw ash the compressive strength is increased

4.4 SIMPLE SLUMP TEST

A slump test was performed on all 4 concrete mixes to ascertain workability according to ASTM C143. For this test, 4 mixes with a mix ratio of 1:1.5:4. Specific water-cement ratios and different percentages of rice husk ash and building wire chopped content were prepared and tested for slump test cone. The filling was done in 3 layers, each layer was stamped with a standard 16mm diameter rod, and the top surface of the mix was leveled with the help of the tamping rod. After filling the mold, the cone was slowly lifted, and a decrease in the height of slumped concrete, which is known as slump, was noted to the nearest of 5 mm.

Table 4.5 Slump test with the addition of PP fiber

MIX ID	CEMENT (%)	AGGREGATE (%)	PPF (%)	WSA (%)	WATER CEMENT RATIO	ADMIXTURE	SLUMP VALUE
M1	100	100	0	0	0.55	1	55
M2	95	100	0	5	0.55	1	48
M3	90	100	0.20	10	0.55	1	45
M4	85	100	0.25	15	0.55	1	40
M5	80	100	0.30	20	0.55	1	34

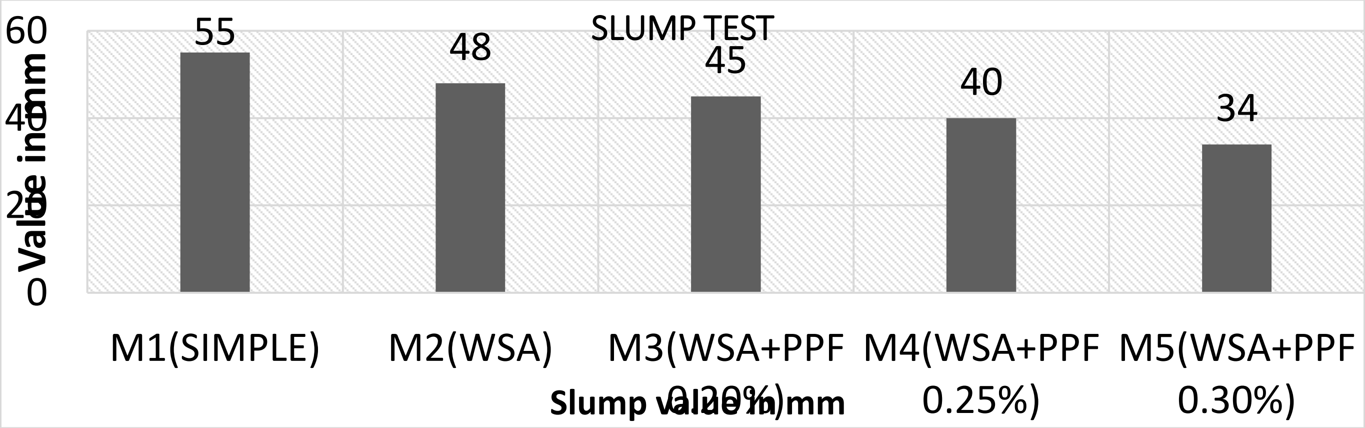


Figure 4.5 Slump test with the addition of PP fiber

SLUMP TEST WITH THE ADDITION OF PP FIBER AND STEEL FIBER

Table 4 6 slump test with the addition of PP fiber and Steel fiber

MIX ID	CEMENT (%)	AGGREGATE (%)	PP FIBER (%)	STEEL FIBER (%)	WHEAT STRAW ASH (%)	WATER CEMENT RATIO	ADMIXTURE SUPER PLASTICIZER (%)	SLUMP TEST WITH PPF AND SF
M6	90	100	0.20	0.20	10	0.55	1	49
M7	90	100	0.25	0.25	10	0.55	1	44
M8	90	100	0.30	0.30	10	0.55	1	39

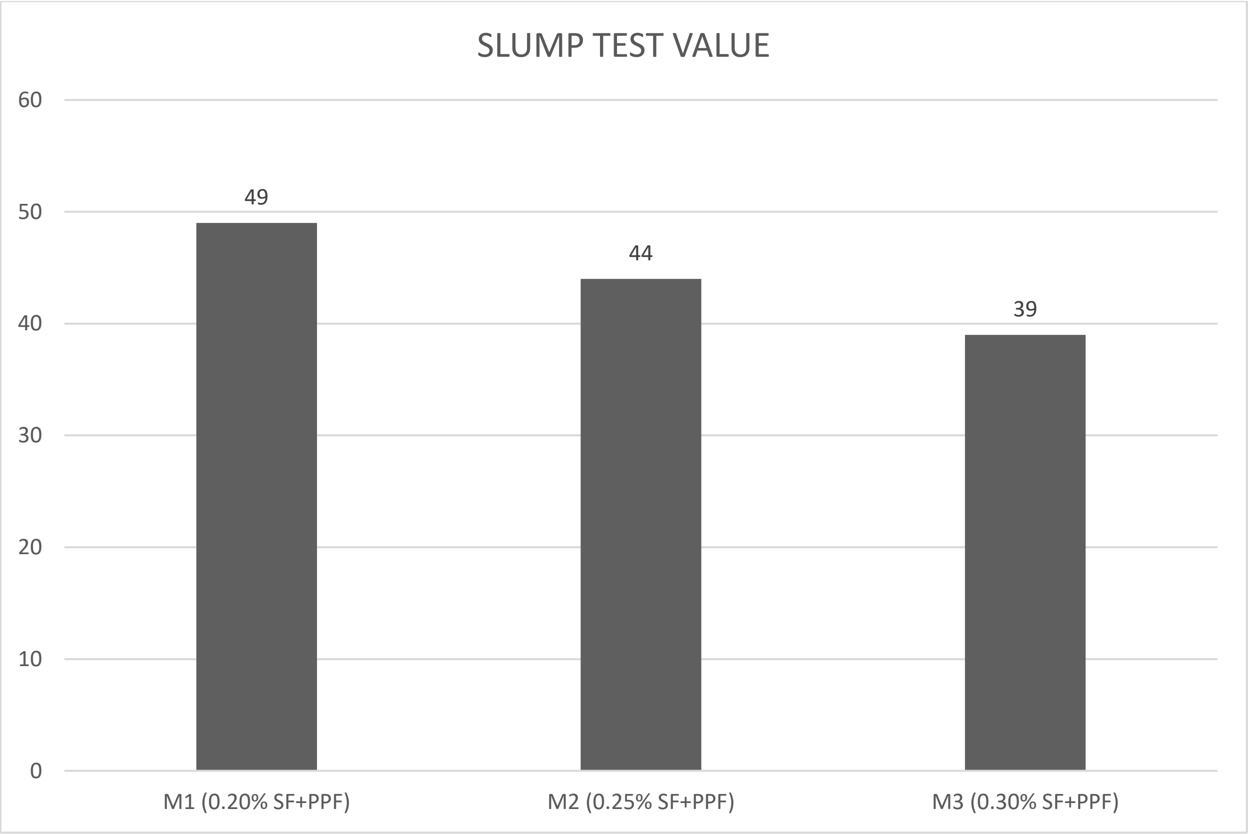


Figure 4.6 Slump stet with the addition of PPF and SF

Graphical representation of results given in Table 4.5,4.6 shown in Figure 4.5,4.6 Figure specify variation in slump value after the addition of steel fibers, Polypropylene Fiber, and wheat straw ash as making a comparison to non-fiber concrete.

This research results show the change in slump value by the addition of different ratios of steel fibers, Polypropylene Fiber, and wheat straw ash in concrete as compared to plain cement concrete. Table 4.5,4.6 represents an increase/decrease in slump value after the addition of steel fibers, Polypropylene Fiber, and wheat straw ash

This has been observed that the addition of steel fibers, Polypropylene Fiber, and wheat straw ash increases the compressive strength of concrete. As we add steel fibers, Polypropylene Fiber, and wheat straw ash the compressive strength is increased

4.5 Split Cylinder Strength

- Table 4.4 shows the results of average split cylinder strength tests achieved on the test samples 28 days of age. The values of tensile strength defined in the table are average values to be achieved by splitting 3 samples at specific ages.

Table 4.4 Calculation of Average split cylinder strength values of different mixes

4.5.1 Split tensile strength with the addition of PP fiber

Table 4.7 Split tensile strength with the addition of PP fiber

MIX ID	CEMENT (%)	AGGREGATE (%)	PP FIBER (%)	WHEAT STRAW ASH (%)	WATER CEMENT RATIO (%)	ADMIXTURE SUPERPLASTICIZER RATIO (%)	SPLIT TENSILE STRENGTH WITH PPF AT 28 DAYS
B1	90	100	0	10	0.55	1	3.8
B2	90	100	0.20	10	0.55	1	4.19
B3	90	100	0.25	10	0.55	1	4.41
B4	90	100	0.30	10	0.55	1	3.98

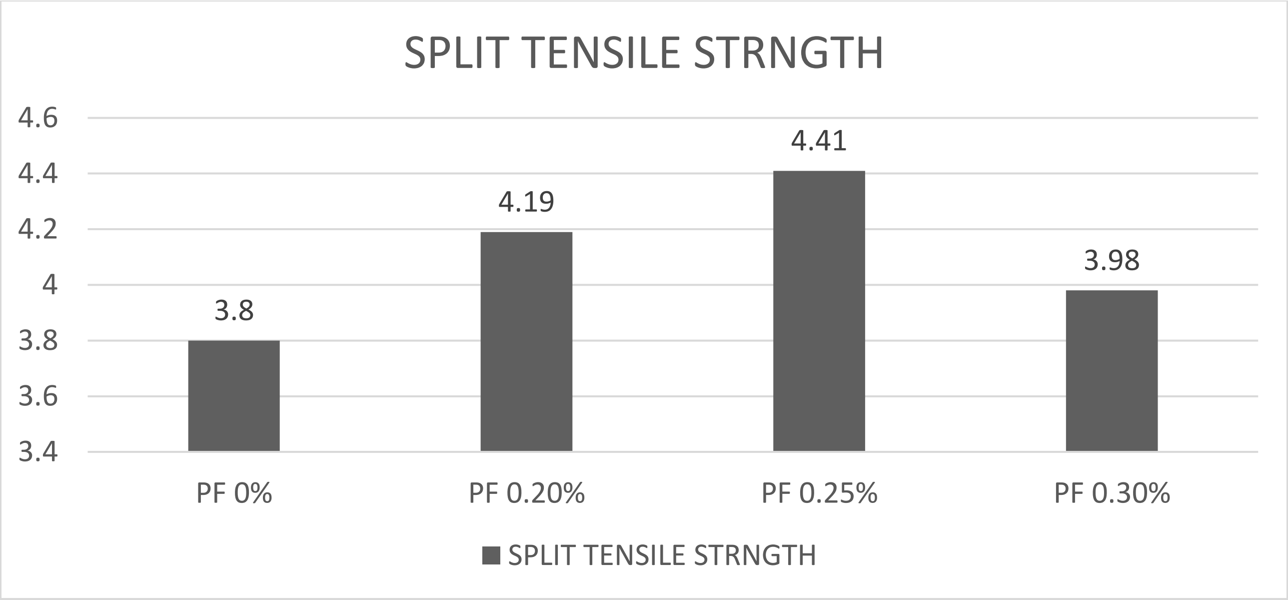


Figure 4 7 Split tensile with the addition of PP fiber

4.5.2 Split tensile strength with the addition of steel fiber

Table 4 8 Split tensile strength with the addition of steel fiber

MIX ID	CEMENT (%)	AGGREGATE (%)	PP FIBER (%)	STEEL FIBER (%)	WHEAT STRAW ASH (%)	WATER CEMENT RATIO	ADMIXTURE SUPER PLASTICIZER (%)	SPLIT TENSILE STRENGTH WITH STEEL FIBER AT 28 DAYS
B5	90	100	0	0.20	10	0.55	1	5.21
B6	90	100	0	0.25	10	0.55	1	5.32
B7	90	100	0	0.30	10	0.55	1	5.15

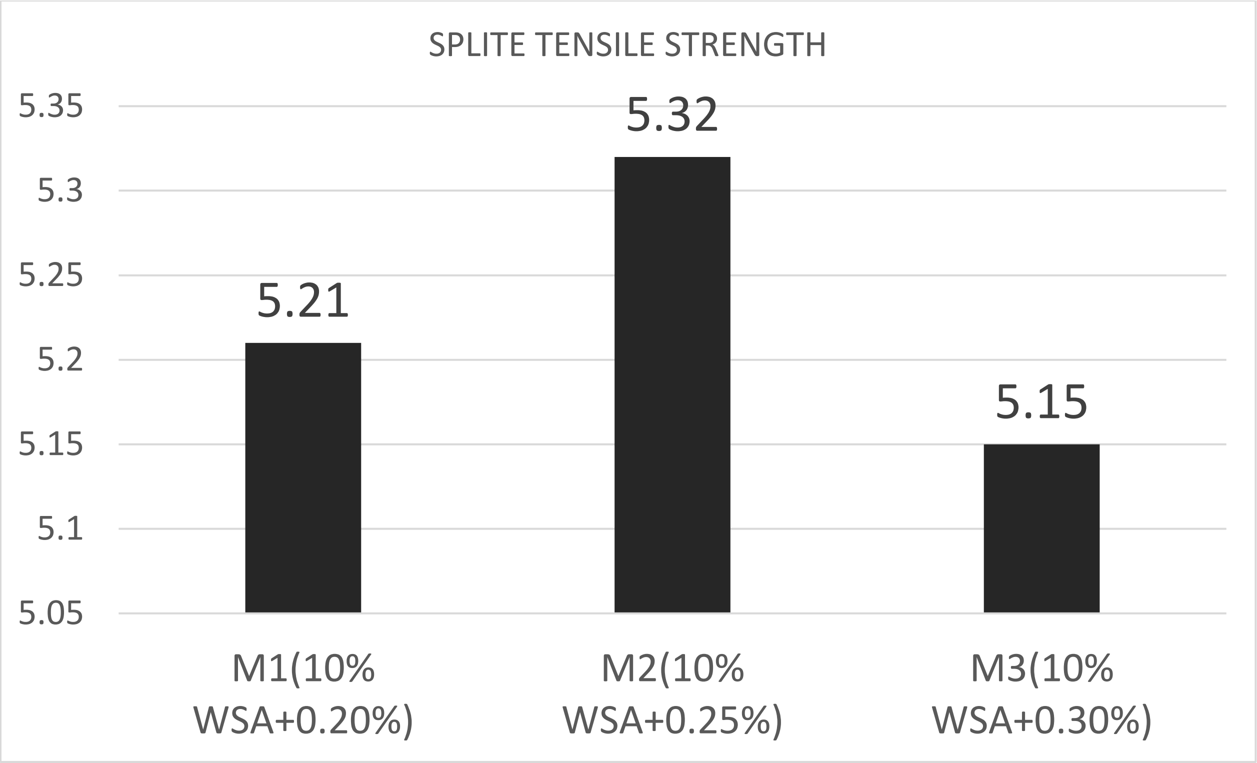


Figure 4.8 Split tensile strength with the addition of steel fiber

4.5.3 Split tensile strength with the addition of PP fiber and steel fiber

Table 4.9 Split tensile strength with the addition of PP fiber and Steel fiber

MIX ID	CEMENT (%)	AGGREGATE (%)	PP FIBER (%)	STEEL FIBER (%)	WHEAT STRAW ASH (%)	WATER CEMENT RATIO	ADMIXTURE SUPER PLASTICIZER (%)	SPLIT TENSILE STRENGTH WITH PPF AND SF
B7	90	100	0.20	0.20	10	0.55	1	5.98
B8	90	100	0.25	0.25	10	0.55	1	6.11
B9	90	100	0.30	0.30	10	0.55	1	5.91

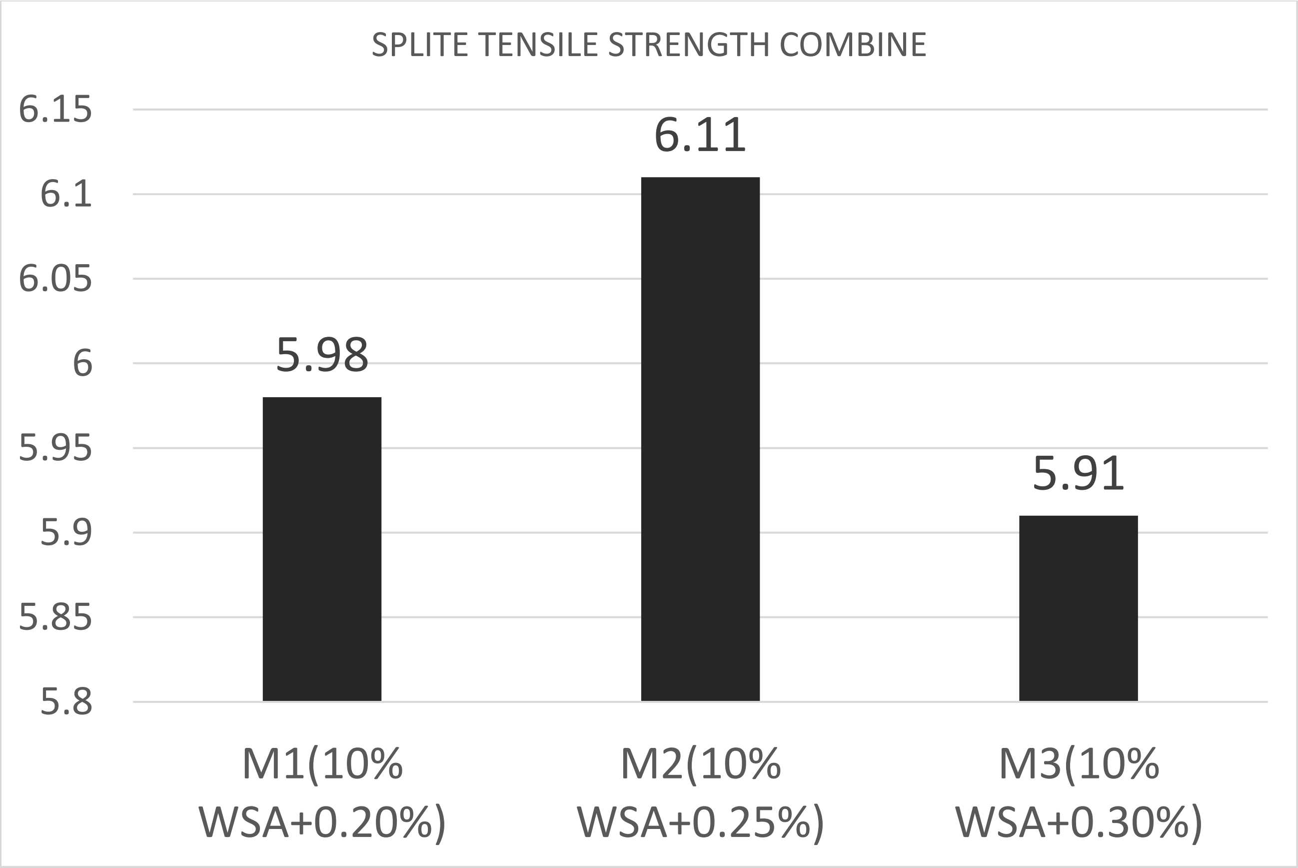


Figure 4.9 Split tensile strength with the addition of PPF and SF

Figure 4.7,4.8, 4.9 Variation of split cylinder strength at different ages with Steel fiber and polypropylene fiber shows

- Split cylinder strength of concrete gradually increases at all mix designs with the addition of steel fiber and wheat straw ash concerning the control mix. This increase in strength was shown in all ages of concrete we tested at 28 days.
- It is also clear that the split cylinder strength of concrete by the addition of steel fiber, polypropylene, and wheat straw ash in concrete is increased at all percentage ratios.

In this research results show the change in strength by the addition of different ratios of steel fiber polypropylene, and wheat straw ash in concrete as compared to plain cement concrete. Table 4.7, 4.8,4.9 represents an increase/decrease in split cylinder strength after the addition of steel fiber polypropylene, and wheat straw ash

4.6 Water Absorption Test

The table shows the water absorption test results of plain and fiber concrete specimens for all mixes. The table shows the water absorption in percentage over 28 days. The displaying values of water absorption

4.6.1 WATER ABSORPTION WITH THE ADDITION OF PP FIBER

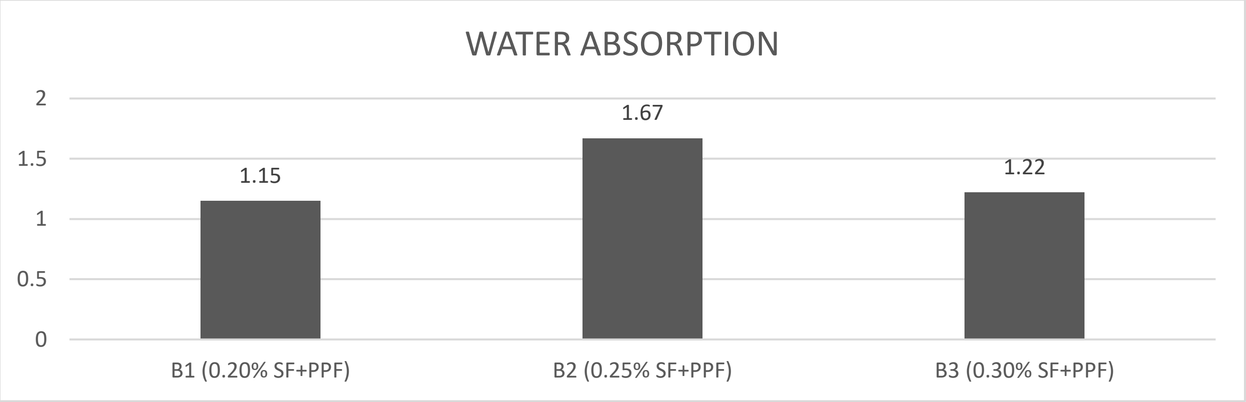
Table 4.10 Water absorption with the addition of PP fiber

MIX DESIGN	W1	W2	W.A (%) W2-W1/W1*100
C1	2.59	2.66	2.70
C2	2.47	2.54	2.83
C3	2.42	2.53	4.54
C4	2.47	2.53	2.42

4 6.2 WATER ABSORPTION WITH THE ADDITION OF STEEL FIBER

Table 4 11 Water absorption with the addition of steel fiber

C5	2.61	2.64	1.15
C6	2.63	2.67	1.67
C7	2.66	2.69	1.22



4.6.3 WATER ABSORPTION WITH THE ADDITION OF STEEL FIBER AND PP FIBER:

Table 4 12 Water absorption with the addition of PPF and SF

MIX DESIGN	W1 (kg)	W2 (Kg)	W.A % W2-W1/W1*100
C8	2.58	2.69	4.26
C9	2.57	2.69	4.66
C10	2.59	2.68	3.5

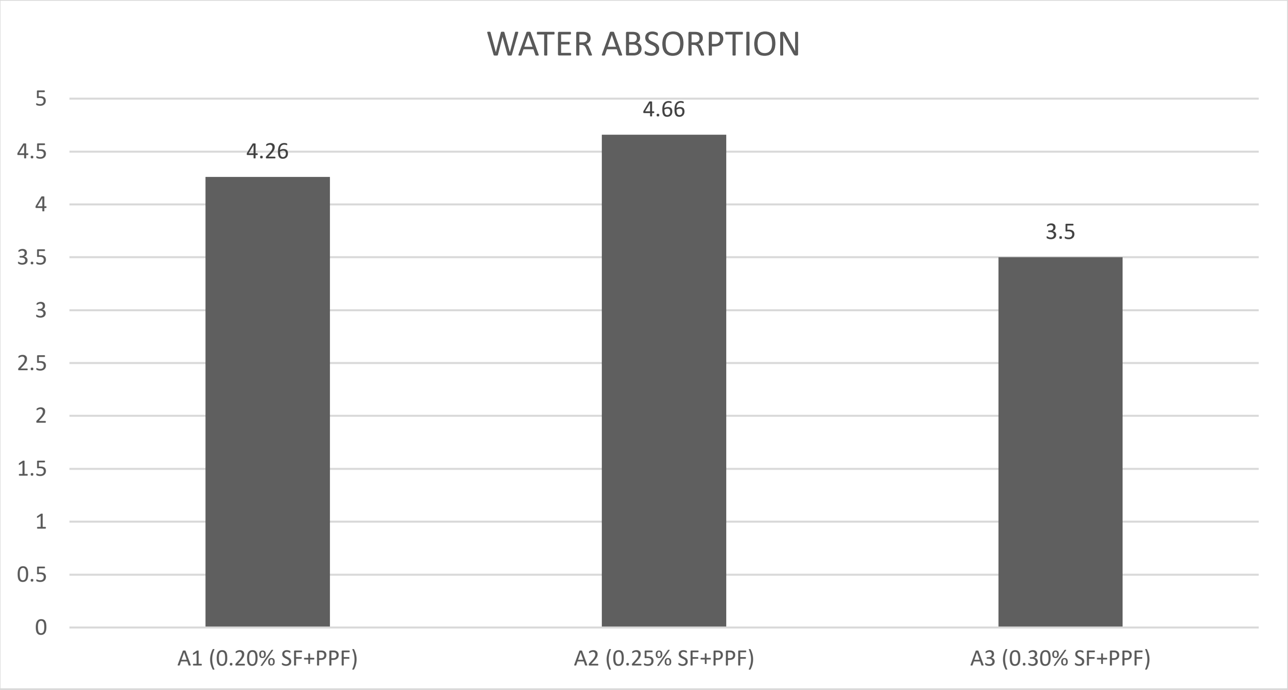


Fig 4.10,4.11,4.12 shows the results of water absorption of conventional concrete and steel fiber polypropylene, and wheat straw ash. As results are shown it is observed that the amount of water absorption of the C9 mix design is higher and the C5 mix design has lower water absorption.

4.6 Micro structure test

The microstructure of concrete refers to the arrangement, composition, and interactions of its various constituent materials at a microscopic scale. Understanding the microstructure is crucial for comprehending the properties and behavior of concrete, as it directly influences its mechanical, durability, and performance characteristics.

The main components of concrete microstructure are:

1. Cement paste: Cement paste is the binder material in concrete, formed by mixing cement, water, and often supplementary cementitious materials (SCMs) like fly ash or slag. The microstructure of cement paste consists of cement hydrates, hydrated cement particles, and capillary pores.

2. Aggregates: Aggregates are coarse and fine materials mixed with cement paste to provide strength and bulk to the concrete. The microstructure of aggregates comprises individual particles and the interfacial transition zone (ITZ), where cement paste and aggregate particles meet.

3. Pores: Concrete contains various types of pores, including capillary pores, gel pores, and air voids. These pores influence the permeability and durability of concrete. Capillary pores are particularly important as they allow the movement of moisture and other harmful substances into the concrete.

4. Cement Hydrates: Cement hydrates are the products of the chemical reaction between cement and water. They form a complex network of microscopic crystals that give concrete its strength and binding properties.

5. Interfacial Transition Zone (ITZ): The ITZ is the region where the cement paste and aggregate particles come into contact. It plays a crucial role in transferring stress between the two materials and influences the overall strength and durability of the concrete.

6. Other materials: In some cases, concrete may contain supplementary materials like admixtures or fibers, which can affect the microstructure and properties of the concrete.

The microstructure of concrete can be analyzed using various microscopic techniques, such as scanning electron microscopy (SEM) and optical microscopy. By studying the microstructure, researchers and engineers can gain insights into the performance of concrete under different conditions, identify potential issues, and develop strategies to enhance its properties and durability.

4.7 FTIR TEST

FTIR stands for Fourier Transform Infrared Spectroscopy. It is an analytical technique used to identify and analyze the chemical composition of materials, including concrete. FTIR spectroscopy measures the absorption of infrared radiation by the sample, providing information about the molecular bonds present in the material.

In the context of concrete, FTIR spectroscopy can be used to study the chemical composition of cement paste and other cementitious materials. Here's how FTIR analysis is applied to concrete:

1. Sample Preparation: To perform FTIR analysis on concrete, a small sample of the cement paste or other cementitious components (e.g., supplementary cementitious materials) is typically collected. The sample is then ground into a fine powder to facilitate analysis.

2. FTIR Measurement: The powdered sample is placed in the FTIR spectrometer, and infrared light is passed through it. As the infrared radiation interacts with the sample, certain chemical

bonds in the material absorb specific wavelengths of the infrared light, leading to characteristic absorption peaks in the resulting spectrum.

3. Interpretation: The FTIR spectrum obtained from the concrete sample provides valuable information about the chemical functional groups present in the material. Each peak in the spectrum corresponds to specific molecular bonds, and their intensity and position can be used to identify various compounds.

4. Analysis and Applications: FTIR analysis of concrete can help identify the presence of key components, such as calcium silicate hydrates (C-S-H), calcium hydroxide (CH), and other phases that form during cement hydration. It can also detect the presence of supplementary cementitious materials like fly ash or slag, which are commonly used in concrete to enhance its properties. Additionally, FTIR analysis can provide insights into the degree of hydration and the distribution of certain chemical compounds in the concrete microstructure.

FTIR spectroscopy is a powerful tool for researchers and engineers working on concrete characterization and optimization. It complements other techniques like X-ray diffraction (XRD) and scanning electron microscopy (SEM) to provide a comprehensive understanding of the concrete's composition, microstructure, and properties. By gaining a deeper understanding of the chemical aspects of concrete, engineers can develop more effective and durable concrete mixes for various construction applications.

4.7.1 FTIR FOR 0.20%:

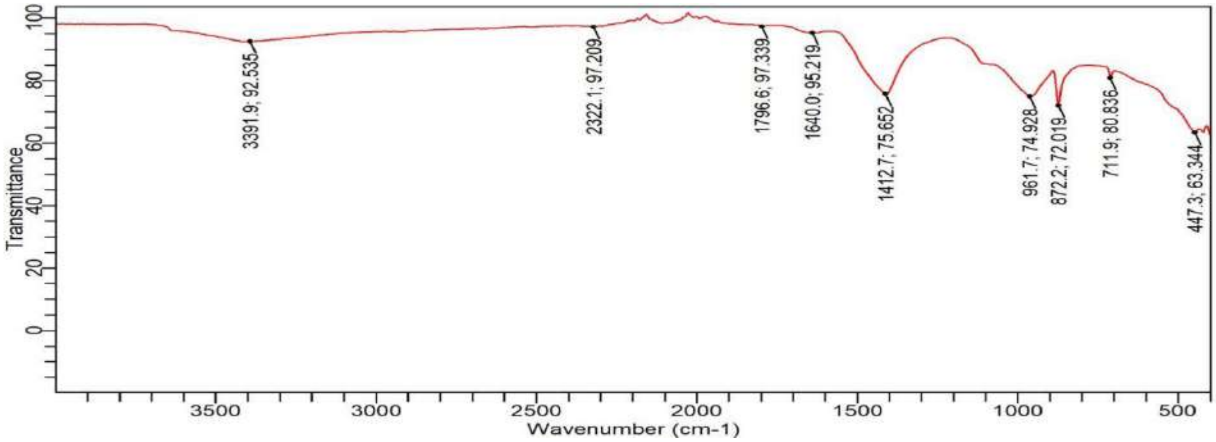


Figure 4 10 FTIR vale at 0.20% ratio

4.7.2 FTIR FOR 0.25%:

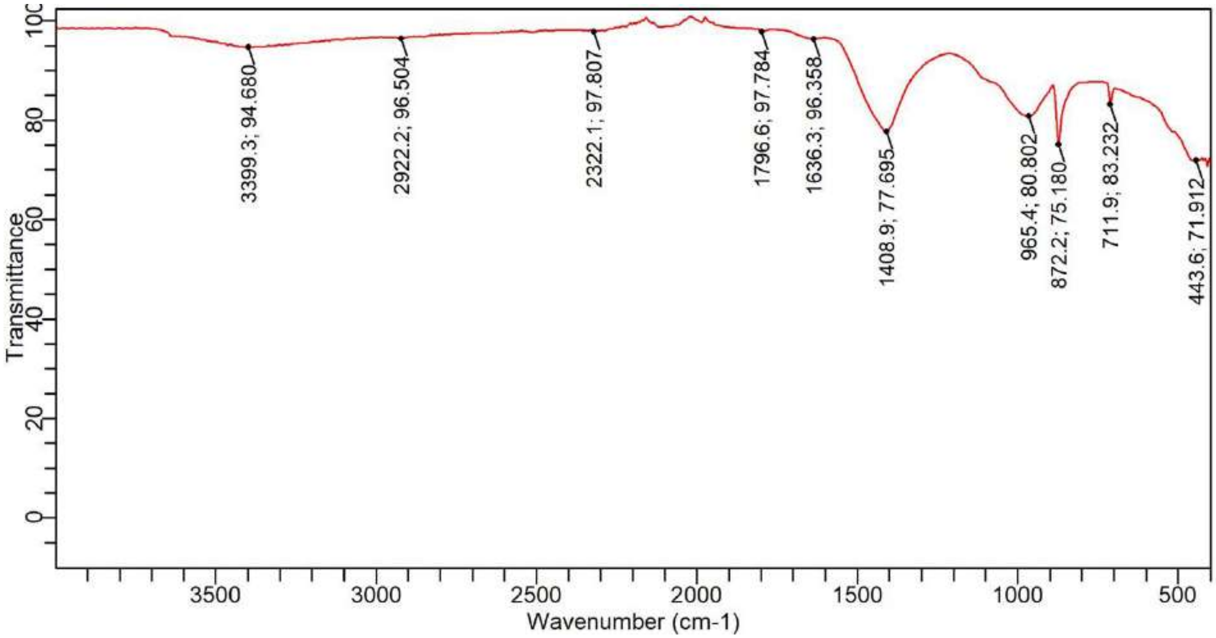


Figure 4 11 FTIR vale at 0.25% ratio

4.7.3 FTIR FOR 0.30%:

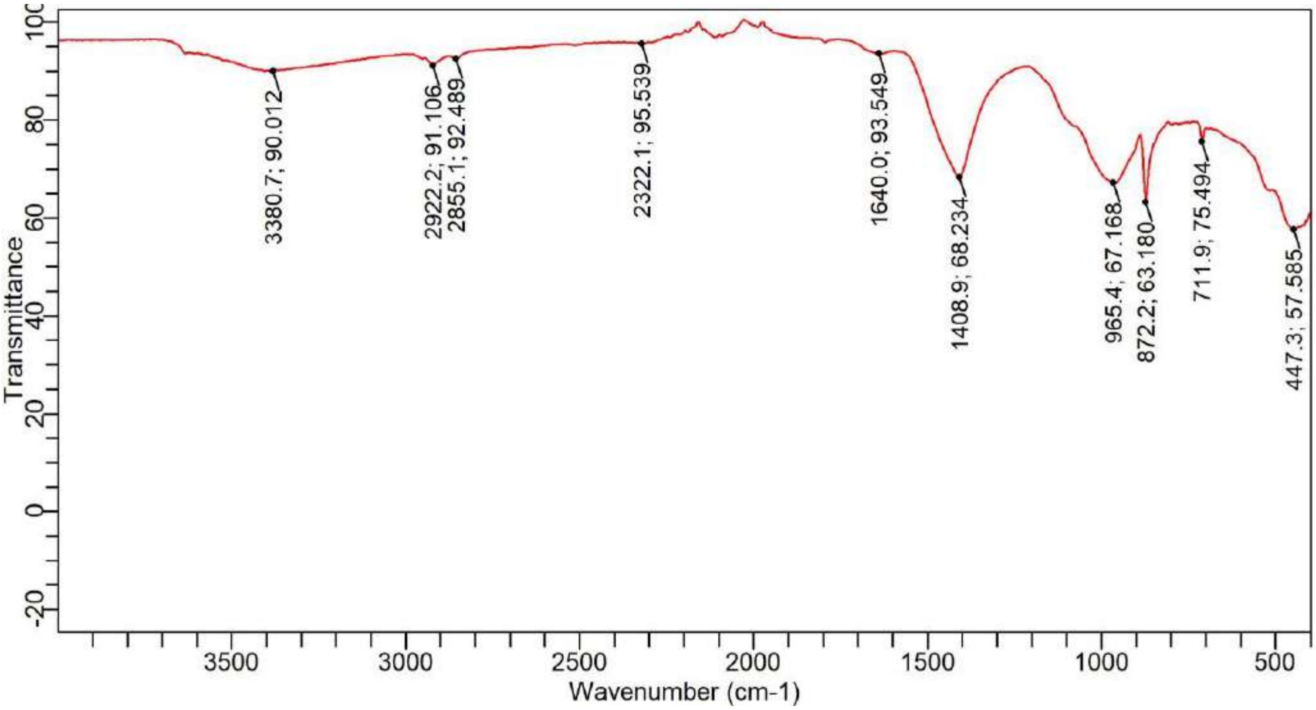


Figure 4 12 FTIR vale at 0.30% ratio

4.7.4 FTIR WITH MAXIMUM VALUE FOR ALL RATIO

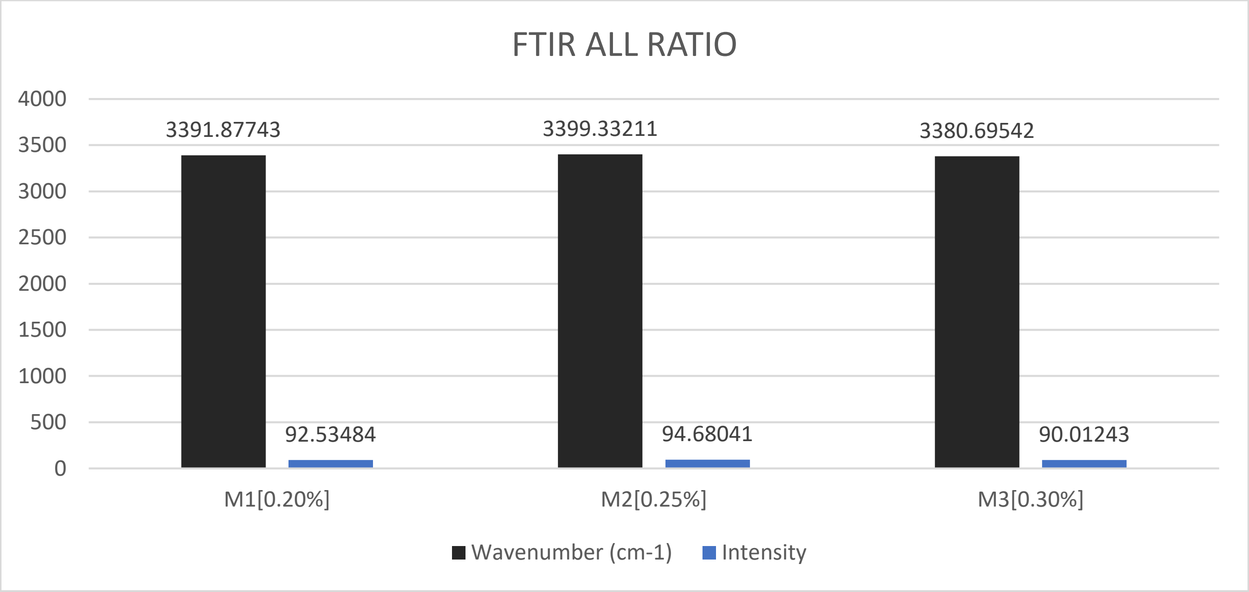


Figure 4 13 FTIR value of all ratio

4.8 SEM stands for Scanning Electron Microscopy

In the context of concrete, SEM stands for Scanning Electron Microscopy. It is an advanced microscopy technique used to study the microstructure and surface morphology of materials, including concrete. SEM provides high-resolution images and allows researchers and engineers to observe the surface of concrete at a microscopic level.

Here's how Scanning Electron Microscopy works and its significance in studying concrete:

1. Principle: SEM uses a focused beam of electrons to scan the surface of a sample. When the electron beam interacts with the sample's surface, various signals are generated, including secondary electrons, backscattered electrons, and characteristic X-rays. These signals are then detected and used to create an image of the sample's surface.

2. Sample Preparation: Before conducting SEM analysis, concrete samples need to undergo proper preparation. This typically involves cutting the concrete into small pieces, polishing the surface to make it smooth, and coating it with a thin layer of conductive material (e.g., gold) to avoid charging effects during electron beam scanning.

3. Microstructure Analysis: Once the concrete sample is prepared, it is placed inside the SEM chamber, where the electron beam scans the surface. The SEM images produced provide detailed information about the arrangement of cement particles, aggregates, pores, and other micro-structural features of the concrete. This allows researchers to examine the cement paste-aggregate interface, the distribution of pores, the structure of the C-S-H gel, and the presence of any defects or cracks.

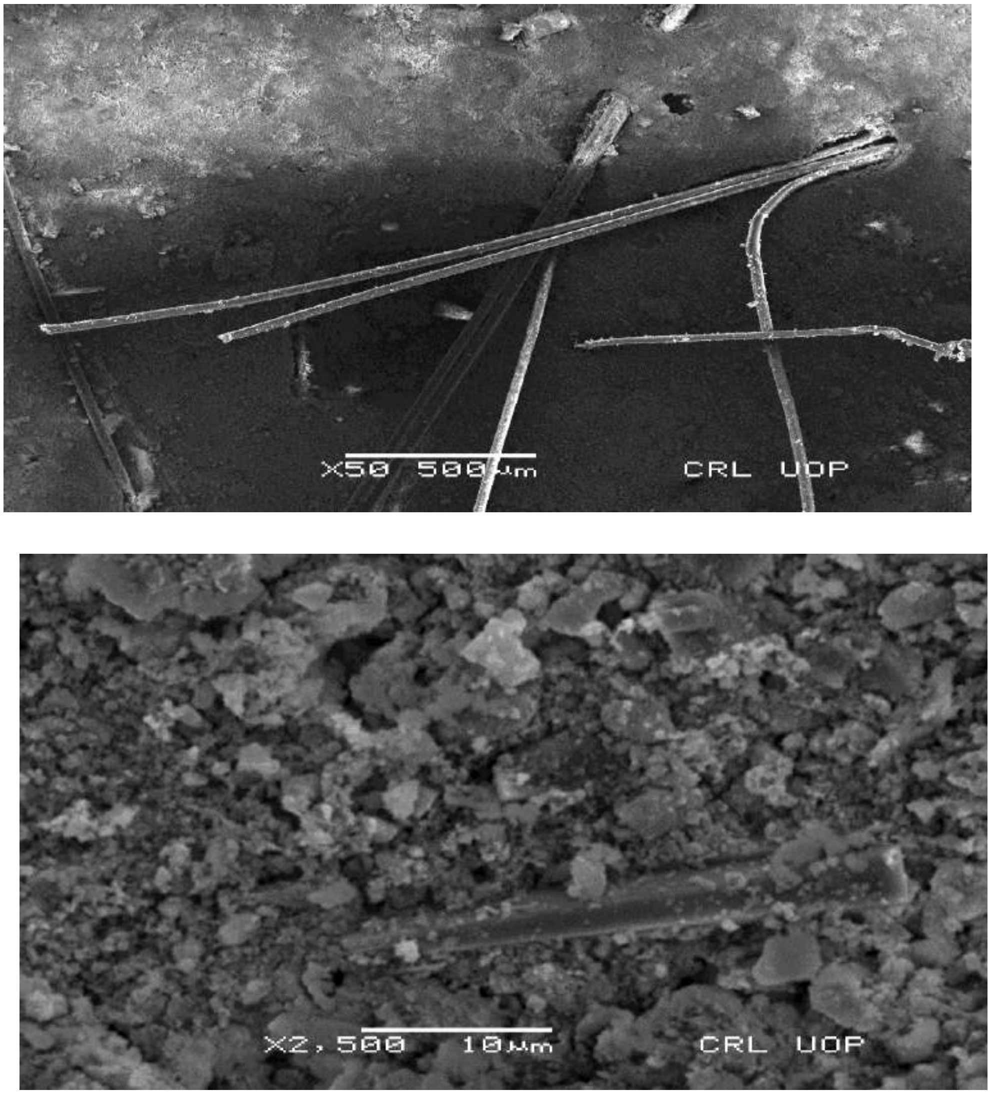
4. Insight and Understanding: SEM analysis of concrete microstructure is crucial for understanding its properties, performance, and durability. It helps researchers identify the quality of cement hydration, the effectiveness of various additives, and the impact of different mix designs. By

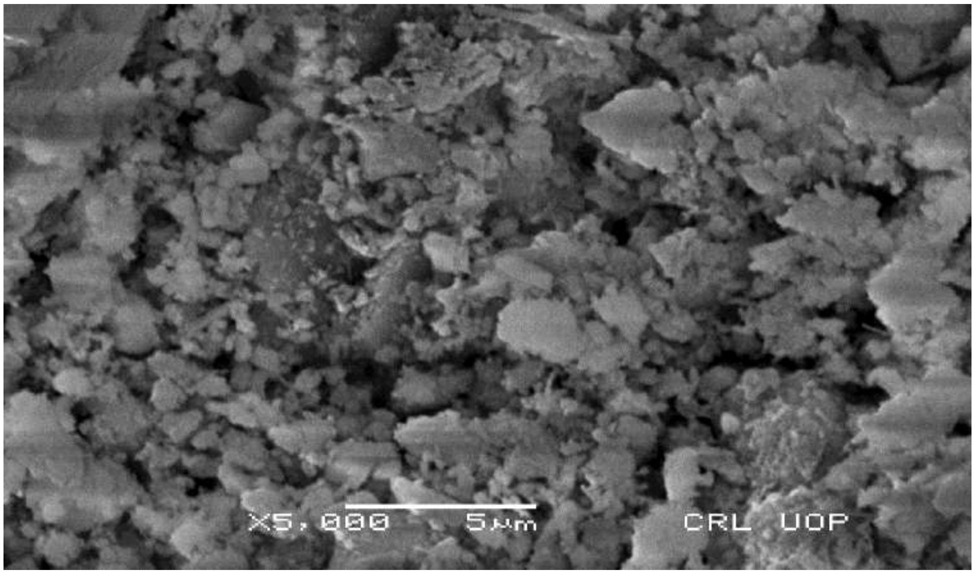
gaining insights into the microstructure, engineers can optimize concrete compositions, enhance its strength, durability, and other engineering properties, and develop concrete mixes suitable for specific applications and environmental conditions.

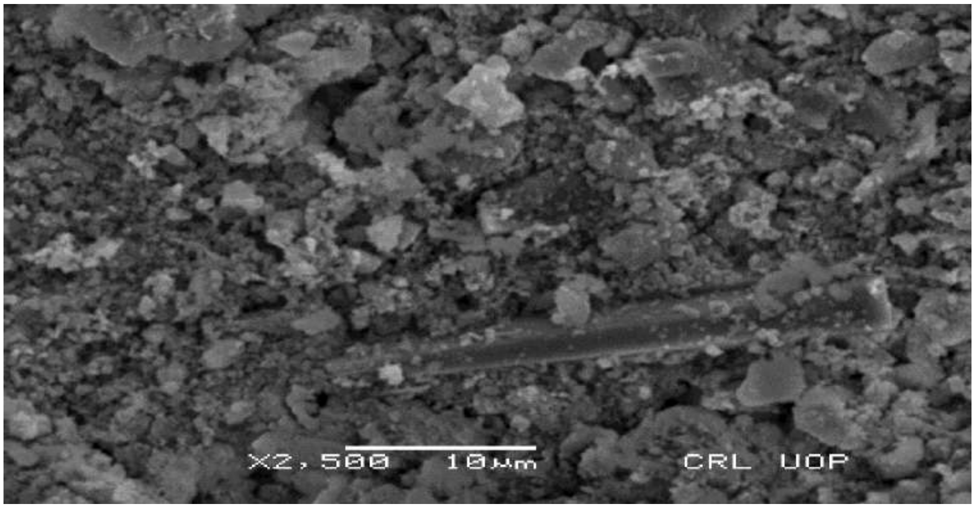
It's important to note that SEM is a sophisticated and expensive technique mainly used in research and specialized laboratories. Regular quality control and construction practices do not typically involve SEM analysis, but it remains a valuable tool for investigating concrete behavior and improving its performance in specialized applications or challenging environments.

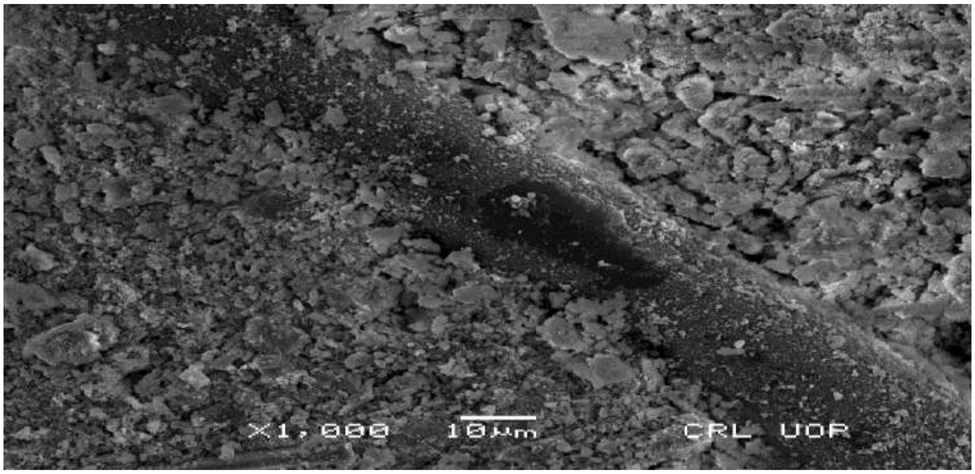
4.8.1 SEM FOR 0.20% Polypropylene Fiber and steel fiber combine

Figure 4 14 SEM for 0.20% of PPF and SF



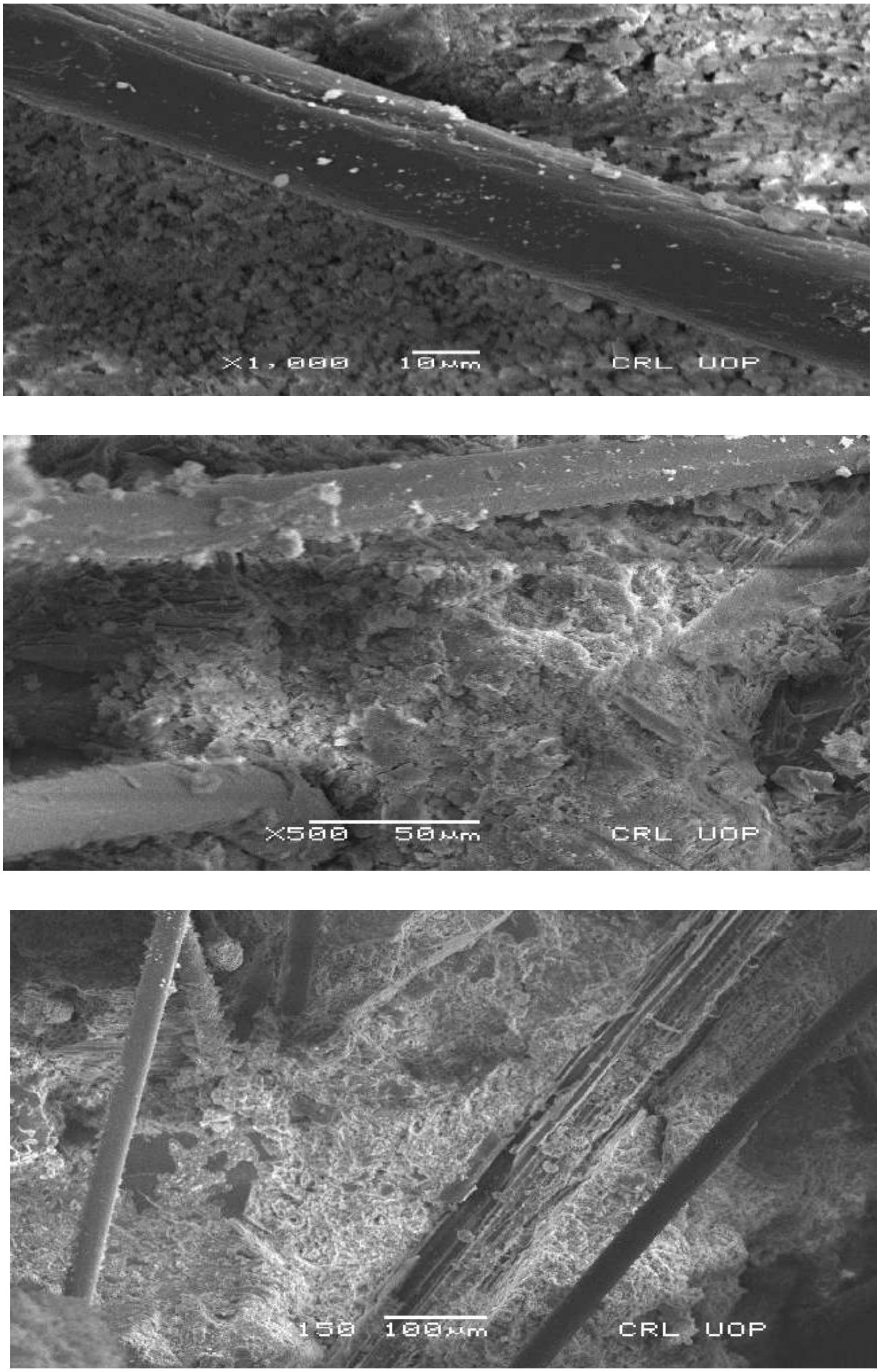

X5,000 5µm
CRL UOP

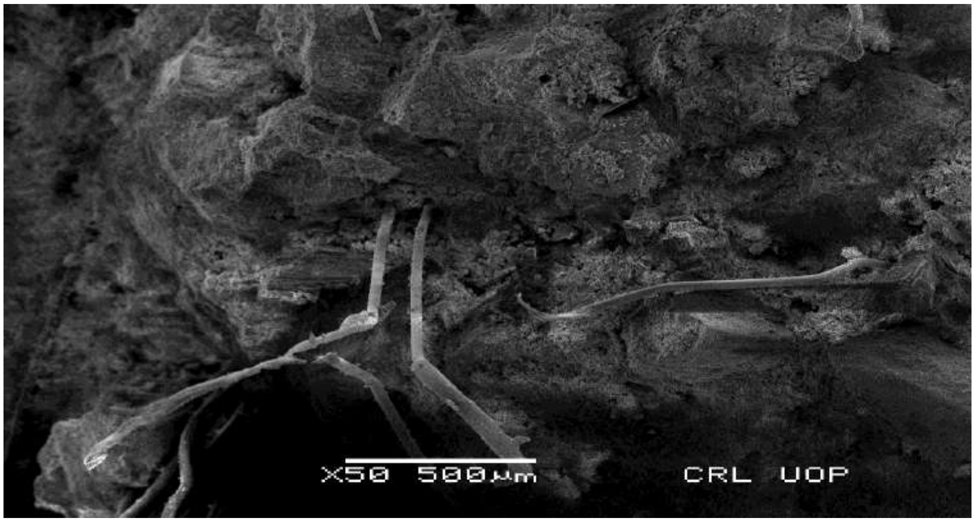

X2,500 10µm
CRL UOP


X1,000 10µm
CRL UOP

4.8.2 SEM FOR 0.25% Polypropylene Fiber and steel fiber combine

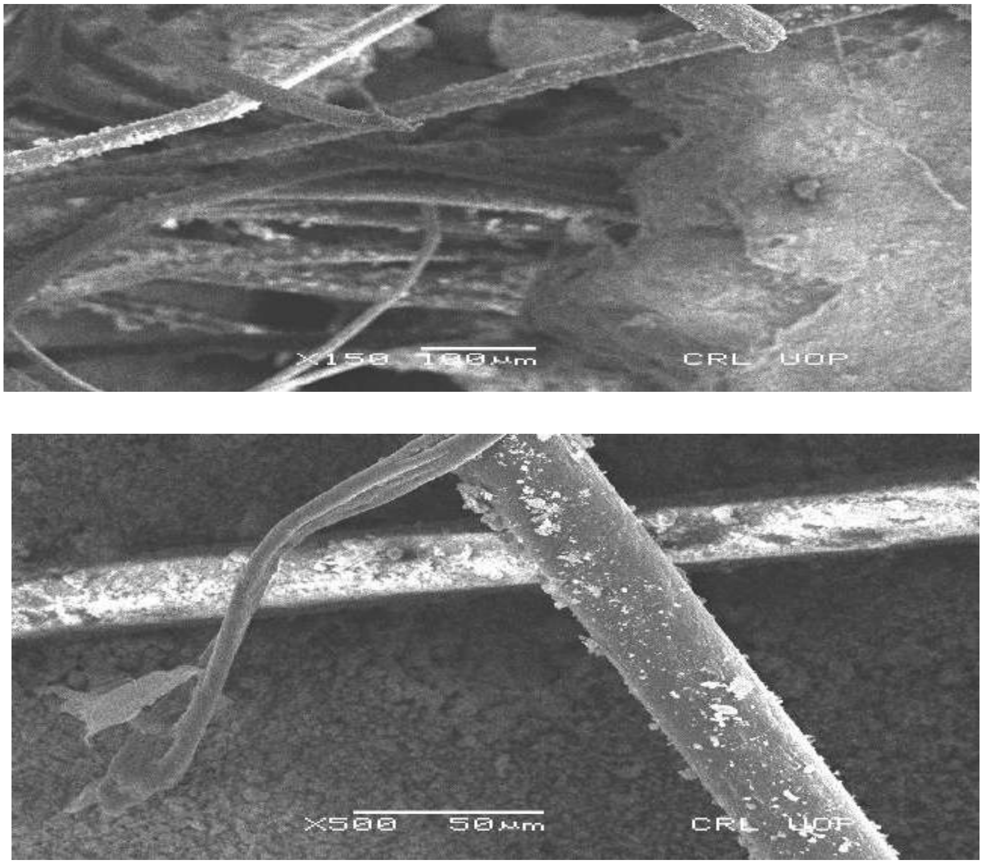
Figure 4 15 SEM for 0.25% of PPF and SF

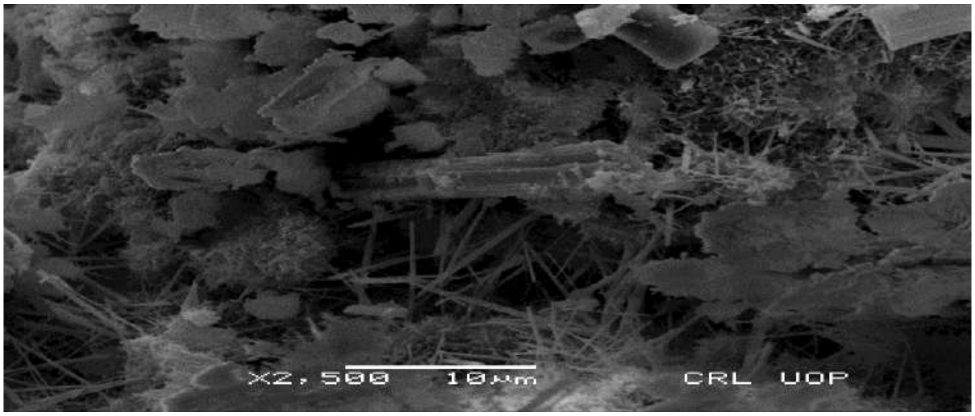




4.8.3 SEM FOR 0.30% Polypropylene Fiber and steel fiber combine

Figure 4 16 SEM for 0.30% of PPF and SF




X2,500 10µm CRL UOP

Chapter V

5 Conclusions and Recommendations

5.1 Preface of the Chapter:

In this chapter, the overall conclusions derived from all the results and testing procedures are given. In this chapter, the recommendations for future researchers are also given.

5.2 Conclusions:

- The maximum compressive strength is obtained at the A13 mix which is 37.25 MPa at 28 days. The minimum compressive strength at the A1 mix is 26.32 MPa at 28 days.
- The results indicate that the maximum increase in strength is 21% at 28 days.
- The maximum split tensile strength is obtained at the B8 mix which is 6.11 MPa at 28 days. The minimum split tensile strength at the B1 mix is 3.8 MPa at 28 days.
- The results indicate that the maximum increase in strength is 40.14% at 28 days.
- The water absorption test indicates that the absorption of water is increased by adding Steel fiber, PP fiber, and WSA. The minimum value of water absorption is at the controlled mix while the maximum value of water absorption is achieved at C8.
- The durability test against aggressive acid indicates that there is maximum weight loss against the controlled mix while minimum weight loss against the C5 mix. The loss of compressive strength is maximum in M5 samples while it is minimum in the controlled mix.

In the current research, cement, and sand are substituted by WSA to improve concrete performance. Concrete strength was further assessed using steel fibers by 0.25% of cement weight. The following conclusions are Drawn from the current research

1. Concrete made with WSA, WSA, and steel fibers significantly improved the mechanical strength of concrete by 43%, 59%, and 45.96% for compressive, and split tensile, respectively.
2. WSA and steel fibers also enhanced the durability considerably as water absorption and porosity were reduced by 15.9% and 29%.
3. Adding WSA, WMP, and steel fibers reduced the concrete workability a lot. W10 S 0.25 concrete sample had the least value as compared to the control sample.

5.3 Recommendations

- The research is carried out on a limited number of samples due to time constraints; number of samples can be increased if the time constraints are not critical.
- The study is carried out on samples of 28-day strengths, there is a potential gap for future researchers to study the effect of Steel fiber. Polypropylene fibers and WSA concerning the aging of concrete i.e., 28 days strength parameters can be studied.
- There were some human and systematic errors including compression testing machines, these errors can be minimized using better testing equipment.
- A blend of other agricultural wastes can also be used alongside wsa and steel fiber, Polypropylene Fiber.

Chapter VI

6 References

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