

# **The Effect and Adding of Polypropylene Fibers and Silica Fumes as Partial Replacement of Cement on Concrete**

**Muhammad Ammar Masood<sup>1</sup>, Muhammad Husain Masood<sup>1</sup>, Muhammad Awais Akbar<sup>1</sup>, Waqas Aziz<sup>1</sup>, Areej Zahra<sup>1</sup>, Ahsan Ahmad<sup>1</sup>, Muhammad Sohaib<sup>2</sup>, Ibtassam Ahmad<sup>3</sup>**

<sup>1</sup>Department of Civil Engineering, School of Engineering & Technology, Institute of Southern Punjab, Multan

<sup>2</sup>Planning Engineer, National Logistic Corporation (NLC-Engineers), Lahore, Pakistan

<sup>3</sup>Department of Civil Engineering, Faculty of Engineering, University of Engineering & Technology, Taxila, Pakistan

**Abstract.** Cement concrete is the most widely used construction material worldwide. According to a survey, the production of concrete in one day globally equals the total concrete used in the Three Gorges Dam in China. The reason for its extensive use is its good workability and ability to be molded into any shape. Due to such extensive use of concrete in the construction industry, modifications in traditional cement concrete have become mandatory. So, we have to look for some alternate materials having the potential to be used as a replacement for Cement. Polypropylene Fibers and Silica Fumes are two of those ingredients that can be utilized in place of cement to produce the concrete. In this paper, the effect of replacement of cement with Silica fumes on the compressive strength of concrete was assessed by replacing in 3 different ratios of 5, 10, and 15% and addition of fibers in concrete. Experimental work showed that with increase in percentage replacement of cement over silica fumes in concrete, there was increase in compressive strength of concrete. The 28-days compressive strength of 15% silica fumes decreased. In case of addition of polypropylene fibers, 28-days tensile strength increased up to 0.4% addition. Flexure Strength is also increased by the addition of Polypropylene fibers.

**Keywords:** Silica fumes, Polypropylene Fibers.

**Email address:** [ahsanahmad8090@gmail.com](mailto:ahsanahmad8090@gmail.com),

## **1. Introduction**

Concrete's versatility, durability, sustainability, and economy have established it as the world's most widely used construction material. The term concrete refers to a mix of aggregates, usually sand, and either gravel or crushed stone, held together by a binder of cementitious paste. The paste is typically made from Portland cement and water and should also contain supplementary cementing materials like slag cement, silica fumes, and chemical admixtures. However, the use of cement as a binder in a concrete mixture is often criticized by those concerned with environmental conservation. With the increased use of cement in concrete, there are

environmental concerns both in terms of damage caused by the extraction of raw materials and the emission of CO<sub>2</sub> during cement manufacture. Enormous efforts are being made worldwide to reduce the use of hydraulic cement in concrete. These efforts include the use of silica fumes in the partial replacement of cement and the addition of polypropylene fibers in concrete.

Nowadays, many engineers are in the process of seeking various natural and modern methods for the production of construction materials, specifically concrete. They are also focused on maintaining its quality and strength, thus incorporating various other materials as replacements for

specific components in concrete. One such material is silica fumes, and another is polypropylene fibers. These can be utilized in concrete by partially replacing cement with silica fumes, which is a vital component in concrete. Concrete is an extremely useful building material due to its properties such as compressive strength, stiffness, low thermal and electrical conductivity, and its ability to be molded into desirable designs. But it lacks in few properties against like ductility, flexibility and crack control. The syndicate carried out search on internet to various books and found out that Polypropylene Fibers and Silica Fumes can be helpful in devising the mechanical strength of concrete. Use of Polypropylene fibers in concrete considerably increases the flexibility and ductility while the use of Silica fumes provides an increase in compressive strength. So, these mechanical properties which can be helpful in making the higher strength concrete.

***Defining Problem Area:***

Unfortunately, the use of structures designed with high strength concrete is not very common in Pakistan like in hilly areas where earthquakes are very common. The reason is that either they are too expensive or materials to be used are not available in Pakistan. So by the introduction of higher strength concrete using locally available material will cut down the cost and will provide the local industry with indigenous techniques of making human life safe

***Research Scope:***

The research reported herein focused on the strength characteristics of concrete after partially replacing cement with silica fumes, which increases the compressive strength of concrete. Additionally, the inclusion of polypropylene fibers in the concrete enhances its tensile and flexural strength.

***Study Limitations:***

The work carried out aims to primarily enhance certain mechanical properties of concrete through the addition of silica fumes and polypropylene fibers. The respective mechanical properties are then tested in the laboratory, analyzed, and compared with those of conventional concrete.

**2. Literature Review**

The past work regarding the use of silica fumes and polypropylene fibers in concrete have been reviewed and are presented below: D. Prasanya, S. Vignesh, et al. (2016) studied the effects of replacing 5-25% cement with silica fume (SF) and adding 0.1% polypropylene (PP) fibers on concrete's mechanical properties. The optimal mix, SF10PP0.1, showed a 27.18 N/mm<sup>2</sup> increase in compressive strength at 28 days. Rishav Garg and Rajni Garg (2020) analyzed the effects of substituting cement with SF (4%-16%) and PFW (0.4%-1.6%) on compressive strength at 7, 28, and 90 days. They found significant strength improvements: up to 16% with SF and 26% with PFW. Optimal substitution (12% SF and 1.6% PFW) increased compressive strength by 31% after 90 days. Vithal Biradar and Prof. Nadeem Pasha et al. (2016) experimented with hybrid fiber concrete using polypropylene fiber and silica fume in M25 and M30 concrete. With varying hybrid ratios (0%, 1%, 1.5%, 2%), they found significant improvements: at 28 days, CS was 41 MPa, TS was 7 MPa, and FS was 9 MPa. Silica fume increased compressive strength by 12-18%, and PPF content by 1-1.5%. Mahendra Prasad et al. (2013) used OPC, coarse aggregate, river sand, silica fume, tap water, and polypropylene fibers. Flexural strength tests showed that adding 0.6% PF and 10% SF improved strength from 3.65 MPa to 4.95 MPa at 7 days and from 5.19 MPa to 7.32 MPa at 28 days. Optimal flexural strength was achieved with 0.4% PF and 10% SF, resulting in a 41% improvement compared to reference concrete. Hongwei Wang (2012) investigated the effects of polypropylene

fibers on the compressive and flexural properties of concrete with silica fume. The study showed that compressive and flexural strengths increase with fiber volume fractions up to 0.12%. The compressive strength increase is significant from 0.04% to 0.1%. However, the flexural modulus of elasticity decreases with higher fiber content. Husain Masood, Shahzaib Ali et al (2010) studied the effects of adding silica fumes (10%) and polypropylene fiber (0.9, 1.8, 3.6 kg) on concrete's mechanical properties. FC1 showed a 53% increase in compressive strength, while FC2 and FC3 showed 47% and 15%, respectively. FC2 had the highest flexure resistance and tensile strength, with increases of 70% and 61%, respectively, compared to the PC mix. Mahmoud Nili and V. Afroughsabet (2009) analyzed concrete with WC ratios of 0.36 and 0.46, utilizing polypropylene fibers at concentrations of 0%, 0.2%, 0.3%, and 0.5%, along with an 8% replacement of cement with silica fume. The results showed that the addition of silica fume enhances fiber dispersion and strength properties, with 0.5% fiber improving compression, split tension, flexure strength, and impact resistance. Houssam A. Toutanji (1999) investigated concrete with polypropylene fibers (0.1%, 0.3%, 0.5%) and silica fume (up to 10%) for enhanced mechanical properties. The optimal mix for compressive strength was 0.3% PF and 10% SF (45 MPa). Bond strength peaked at 0.5% PF and 10% SF (16 MPa). PF improved post-peak flexural resistance, with 5% SF and 0.30% PF being optimal for reducing permeability while maintaining workability.

### ***Polypropylene Fibers***

Over the past decade, extensive research has focused on synthetic fiber-reinforced concrete, especially polypropylene fiber-reinforced concrete. Polypropylene fibers, Shown in Fig.1 produced via an extrusion process, are created by hot drawing material through a die, forming continuous filaments. These fibers are then slit

into tapes and mechanically distressed to form a lattice pattern, resulting in collated, fibrillated fibers cut to desired lengths. The addition of polypropylene fibers to concrete enhances strain capacity, toughness, impact resistance, and crack control, which are often more critical than tensile strength. Polypropylene is widely used due to its unique properties it is chemically inert, stable in an alkaline environment, has a low melting point, and is cost-effective. These fibers do not absorb water, preventing chemical adhesion with the concrete matrix, and bond through interfacial adhesion and mechanical anchoring. Polypropylene fibers' hydrophobic surface and compatibility with concrete make them ideal for reinforcement applications.

### ***Silica Fumes***

Silica fume is a by-product of reducing high-purity quartz with coal or coke and wood chips in an electric arc furnace during the production of silicon metal or ferrosilicon alloy. It consists of very fine spherical particles with a high amorphous silicon dioxide content. The SiO<sub>2</sub> content in silica fume varies with the type of alloy: 61-84% for 50% ferrosilicon, 84-91% for 75% ferrosilicon, and 87-98% for 98% silicon metal. Silica fume, as shown in Fig.2, was initially seen as a cement replacement and can replace 3 to 4 parts of cement without loss of strength, provided the water content remains constant. However, silica fume increases water demand, necessitating the use of water-reducing admixtures to maintain workability. Increased cohesion in silica fume concrete typically requires a higher slump to maintain the same apparent workability. It is advised to avoid using silica fume in concrete without favorable performance data.



Figure 1. Polypropylene Fibers



Figure 2. Silica Fumes

### 3. Methodology, Experimental Investigation & Material Testing

#### **Material used:**

The materials along specifications, which were used for this experimental program, are summarized below:

#### **Cement:**

OPC (Lucky cement) (ASTM type 1) from Faisalabad, we were used.

#### **Aggregate:**

The coarse aggregate used where natural gravel of Margalla Hills Pakistan with a maximum size of  $\frac{3}{4}$ " , the specific gravity and water absorption percentage were determined in accordance with ASTM C-127- 04." "Whereas the fine aggregate was natural sand of Chenab Pakistan the specific gravity and water absorption percentage were determined in accordance with ASTM C

128-04. The grading of both fine and coarse aggregate was in accordance with the standards specified at ASTM C 136 – 04.

#### **Polypropylene Fibers:**

Fibrillated Polypropylene Fibers, with a specific gravity of 0.9 and 0% water absorption, were utilized. The fibers had a length of 25 mm and a diameter of 0.04 mm, resulting in an aspect ratio of 475. The fiber's melting point ranged from 160°C to 170°C, with an ignition point of 593°C. According to information from the manufacturer (MATRIX Company, Karachi), the fibers exhibited low thermal and electrical conductivities, and high resistance to acids and salts. The Young's modulus of elasticity of the fibers was 3.5 GPa.

#### **Silica Fumes:**

Standard Grey Silica Fumes were used with size  $<4 \times 10^{-6}$  in and specific gravity of 2.2. The Silica Fumes used had a surface area of 60,000 to 150, 000 ft<sup>2</sup>/lb.

#### **Mixing Water:**

The experimental work utilized ordinary drinking water from Faisalabad throughout the study.

#### **Material Representation:**

Several tests were conducted on the material to determine its compliance with ASTM standards.

#### **Tests Performed on Cement:**

Testing and evaluating various properties of cement is essential to ensure its quality and suitability for construction applications. Several standard tests, including all the tests of consistency, setting time and Fineness, are conducted to assess different aspects of cement performance. These tests adhere to specific procedures outlined by ASTM standards to maintain consistency and accuracy in the results.

#### **Normal Consistency Test:**

Normal consistency refers to the water requirement of cement paste at which its viscosity allows a plunger to penetrate a specific depth in a Vicat apparatus. The test is crucial as the amount of water affects cement setting time. The procedure involves mixing a measured quantity of cement with water to form a paste, placing it in the Vicat apparatus, and determining the point at which the plunger settles to the required depth within a specified time frame. After performing this test, our achieved consistency is 27%. The obtained consistency is coming within the Best Range which is 26% to 33%, it is according to ASTM C 187-04. Therefore, the standard consistency of cement paste is 27%.

***Initial and Final Setting Time Test:***

This test determines the duration between water addition and the moment when the cement paste begins losing its plasticity, while the Final Setting Time indicates when the paste completely loses plasticity. Both tests are critical for determining the appropriate duration for transportation, placement, and compaction of cement concrete. The tests involve using needles of specific dimensions to assess the penetration of the cement paste at various time intervals until the desired criteria are met. After performing this test, we got Initial Setting Time is 30 minutes and Final Setting Time is almost 5 hours.

***Soundness Test:***

The Soundness Test evaluates the cement's ability to retain its volume after setting and detects any potential delayed destructive expansion. Unsatisfactory soundness may result from an excessive amount of hard-burned free lime or magnesia, leading to excessive expansion upon setting and the development of cracks in structures. The Le-Chatelier apparatus test is commonly used to determine cement soundness by measuring the expansion of cement specimens subjected to specific conditions. After performing this test, it clarifies that soundness results are within acceptable range.

***Compressive Strength Test:***

This Test assesses the ability of cement mortar cubes to withstand compression. The test involves preparing mortar cubes using standard sand and water, vibrating the mixture to ensure uniform compaction, and curing the cubes under special conditions. After the curing period, the cubes are subjected to compressive loads until failure occurs. The maximum load applied and the cross-sectional area of the cubes are used to calculate the compressive strength. After performing this test, we conclude that the compressive strength of hydraulic cement after 7 days should be 22 MPa according to ASTM C109. So, therefore our results are as same as the specified standard.

***Fineness Test:***

The Fineness Test measures the size distribution of cement particle by sieving it on a standard sieve. The proportion of particles larger than 90 microns is calculated to find the cement fineness. This test is essential as finer cement particles contribute to increased surface area and improved hydration, affecting cement's setting time and strength development. After performing this test, we got shows that the fineness of cement should be lower than 10% according to ASTM C786. So, Fineness of cement is according to the standard limits.

***Tests Performed on Coarse Aggregates:***

Testing the properties of fine aggregates is crucial to ensure their suitability for various construction applications. Several standard tests, including Fineness Modulus, Specific Gravity, Impact Value, and Bulk Density, are conducted to assess different aspects of fine aggregate quality and performance.

***Fineness Modulus Test:***

The Fineness Modulus (FM) indicates the fine aggregates particles average size with the help of an index number. It is determined by doing sieve analysis with the help of

standard sieves. A 2 kg sample of oven-dried fine aggregates is sieved through a set of standard and non-standard sieves, and the mass retained on each sieve is determined. The FM is then calculated by summing the cumulative percentage retained and dividing by 100. After performing this test, it clarifies that “The perfect limit range for fineness modulus of coarse aggregate is 5.5 to 8 according to ASTM C 316 – 05. So, FM of our coarse aggregate is as same as the standard specified range so it is well graded.

***Specific Gravity Test:***

Specific Gravity is defined as the ratio of the weight of an aggregate to the weight of an equal volume of water. Effective Specific Gravity considers all void spaces in aggregate particles except those that absorb asphalt. A 2 kg sample of washed and drained fine aggregates is immersed in distilled water at a specified temperature, and entrapped air is removed. The basket and aggregates are weighed while suspended in water, and the specific gravity is calculated. After performing this test, it clarifies that best limit for specific gravity of coarse aggregate is 2.5 – 3 according to ASTM C127-04. So, specific gravity of our coarse aggregate is within the suitable range.

***Impact Value Test:***

The Impact Value assesses the resistance of fine aggregates to sudden shock or impact, which is crucial for road construction. The test sample consists of aggregates passing through a 14 mm sieve and retained on a 10 mm sieve. The sample is compacted in a cylindrical measure and subjected to 15 blows from a hammer. The crushed aggregate is sieved, and the fractions passing and retained on the sieve are weighed to determine the impact value. After performing this test, it clarifies that as per range of our coarse aggregate has strong impact resistance.

***Bulk Density Test:***

Bulk Density, also known as unit weight, determines the mass/volume relationships for fine aggregates. The test involves determining the dry mass of the original sample, washing it over a 75µm sieve, and determining the dry mass of the washed sample. The sample is sieved through coarse sieves, and the mass of the reduced portion is determined. The percent retained and passing each sieve is calculated to determine the bulk density After performing this test, we got that Density of coarse aggregate should be in the range of 1.45 to 2.082 g/cm<sup>3</sup> according to ASTM C29 - C29M. Our compacted density is according to the range but loose bulk density is slightly lower than the range.

***Test Performed on Fine Aggregate:***

Fine aggregates play a crucial role in various construction applications, and their quality is assessed through several standard tests, including Fineness Modulus, Specific Gravity, and Water Absorption by Pycnometer.

***Fineness Modulus Test:***

The Fineness Modulus (FM) is a measure of the average size of particles in fine aggregates. To conduct the test, a 2 kg sample of oven-dried fine aggregates is prepared. The sample is sieved through a set of standard and non-standard sieves, ranging from 75 mm to 0.15 mm. The mass which is kept on each sieve is weighed, and the percentage passing through each sieve is calculated. The Fineness Modulus is then determined by adding all the cumulative percentage retained and dividing by 100. After performing this test, we got that the fineness modulus of sand should be in the range of 2.3 to 3.1 according to ASTM C 117-05. FM fall within the standard range so sand is well graded.

***Specific Gravity Test:***

Specific Gravity is a measure of the density or relative density of fine aggregates. In the test procedure, a saturated surface-dry (SSD) sample weighing 500 g is

taken and placed in a pycnometer partly filled with water. The entrapped air is removed, and the pycnometer is completely filled with water and weighed. The sample is then oven-dried, and its weight is noted. Specific gravity and apparent specific gravity are calculated using the recorded weights and given formulas. After performing this test, it clarifies that Specific Gravity of fine aggregate should be in between the range of 2 – 3 according to ASTM C128. So, our fine aggregate is fulfilling the standard requirement.

#### ***Water Absorption by Pycnometer:***

Water absorption is another important property of fine aggregates, indicating their ability to absorb water. In this test, approximately 1000 g of material passing the No. 4 sieve is dried to a constant weight in an oven. The sample is then cooled and immersed in water for a specified period. After decanting the water and determining the SSD condition of the sand, a flask pycnometer is calibrated with water. The SSD sand is placed into the pycnometer, filled with water, and weighed. The weight of the pycnometer, specimen, and water is recorded to determine water absorption. After performing this test, it clarifies that Water absorption of fine aggregate should be in the range of according to ATM So, the fine aggregate is fulfilling the standard requirement.

#### ***Test Performed on Concrete:***

##### ***Workability Test of Concrete***

The workability of concrete is a vital property that influences its ease of handling and manipulation during the processes of mixing, placing, consolidation, and finishing. According to ASTM, workability refers to the effort required to manipulate freshly mixed concrete while minimizing the loss of homogeneity. Workability is categorized into three types: unworkable concrete, medium workable concrete, and highly workable concrete. Unworkable concrete, characterized by very low water content, poses challenges for hand mixing and

exhibits high segregation rates. Medium workable concrete, which is suitable for most construction applications, can be easily mixed, transported, placed, and compacted with minimal segregation. On the other hand, highly workable concrete flows readily and settles with little effort, making it ideal for situations where effective compaction is difficult. However, this type of concrete is prone to segregation and loss of homogeneity. Several factors impact the workability of concrete, including the content of cement, water, and the mix proportions. The size, shape, grading, and surface texture of aggregates, along with the use of admixtures and supplementary cementitious materials, also play significant roles in determining concrete's workability.

##### ***Compression Test on Concrete***

Compressive strength is a crucial property of concrete, reflecting its capacity to endure loads without failing. It is calculated as the load applied at the point of failure divided by the cross-sectional area. The equipment required for the compression test comprises a compression testing machine and concrete cubes or cylinders. To perform the test, specimens are extracted from cured concrete samples and allowed to dry. The dimensions and weight of the specimens are documented, and the bearing surfaces of the testing machine are cleaned. The specimens are then placed in the machine, and a gradual load is applied until failure occurs. The average strength of at least three specimens is considered the crushing strength of the concrete.

##### ***Tensile Strength Test***

Tensile strength is another significant property of concrete, particularly in applications like road and runway construction. It is usually measured using the split cylinder test method. The tensile strength of concrete typically ranges from 10% to 12% of its compressive strength. For sample preparation, cylindrical molds are filled with concrete in layers and compacted. The

specimens are cured in water for a specified duration and then tested with a tensile testing machine. The load is applied gradually until failure occurs, and the maximum load is documented.

**Flexure Strength Test**

Flexure strength, also known as modulus of rupture, assesses a concrete beam or slab's capability to withstand bending failure. This test involves subjecting a concrete beam to four-point loading until it ruptures. To perform the test, concrete specimens are prepared by filling molds in layers and compacting them. The specimens are then placed in the testing machine, where a load is applied at a specified rate until failure occurs. The modulus of rupture is determined based on the applied load and the dimensions of the specimen.

**Concrete Mix Design,  $f'_{cr} = 4000$  psi**

The experimental program involved testing hardened concrete specimens for compressive strength, split-tensile strength, and impact resistance. Table.1 outlines the Mix Design, which was used to prepare all concrete specimens with a mix ratio of 1:2:4 and a water-cement ratio of 0.57. Fibers were added as the final ingredients in varying amounts of 0.2%, 0.4%, and 0.6% per cubic meter of concrete.

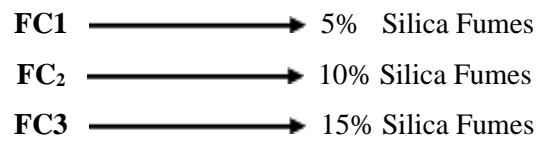
Table 1. Mix Design (ACI Method)

Step.1	Slump	3"- 4"
Step.2	Maximum Size of Aggregate	3/4 "
Step.3	Mixing Water (ACI Table 6.3.3)	340 lbs./yd <sup>3</sup>
Step.4	W/C ratio (ACI Table)	0.57
Step.5	Amount of Cement	596 lbs./yd <sup>3</sup>
Step.6	Coarse aggregate content (ACI Table 6.3.6) → Weight of coarse aggregate	0.66 0.66×27×100.61 → 1793 lbs./yd <sup>3</sup>
Step.7	Weight of Fresh Cement (ACI Table 6.3.7.1)	3960 lbs./yd <sup>3</sup>
Step.8	Weight of fine aggregate	[3960-(340+596+1793)] → 1231 lbs./yd <sup>3</sup>

**4. Results and Discussions**

**Detailing of Specimen**

Various mixes used in this experiment program were abbreviated in two different forms, namely PC and FC. Specimens that were cast without addition of PP Fibers and Silica Fumes were designated as Plain Concrete (PC) whereas Fibrous concrete (FC) represents the specimens that were cast with the addition of PP Fibers and Silica Fumes.



**Test Mechanism**

For the entire experiment work, four concrete mixes were prepared. These include one mix without addition of PP Fibers and Silica Fumes (PC), and rest of the three mixes with addition of 5%, 10% and 15% Silica Fumes and different proportions of PP Fibers were prepared. Each mix had the same water-cement ratio i.e., 0.57 and slump in the range of 3-4".

**Test Details of Specimen**

Compressive strength test of each mix design was determined according to ASTM specifications C 109M-02 and C-796. In accordance to the provisions of ASTM C 192M – 02, specimens were moist cured in curing tank and then dried before testing. Cylinders were capped before testing for compressive strength.

- Compressive strength Test was carried out at the age of 7 & 28 days shown in Fig.5,6. Testing results shown in Table.2,3 and graphs shown in Fig.3,4.
- In Flexural strength test, sample after 28 days testing shown in Fig.8,9. FS test results shown in Table.4. and graph in Fig.7.

- In Split Tensile strength test, sample after 7 & 28 days curing. Testing results shown in Table.5,6. and graph in Fig.10,11.

Table 2. Compressive Strength Test results @ 7 days (0.4 PP Fibers)

Mix (0.4 PP Fibers)	7 days strength		Average	
	Psi	MPa	Psi	MPa
PC	1463.43	10.09	1456.90	10.045
	1450.38	10.00		
FC1	1872.43	12.91	1869.53	12.89
	1866.63	12.87		
FC2	2322.05	16.01	2319.15	15.99
	2317.70	15.98		
FC3	2111.74	14.56	2113.19	14.57
	2116.10	14.59		

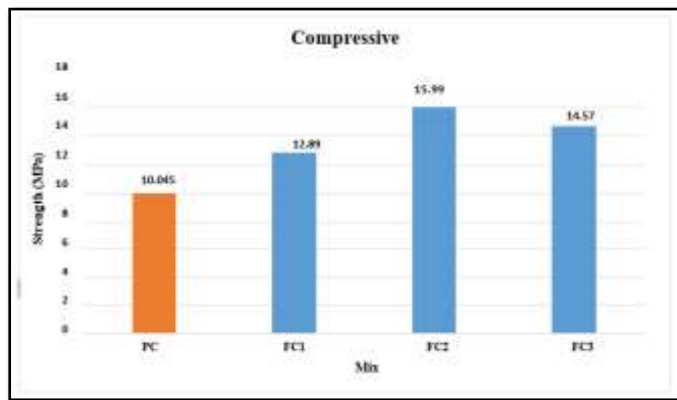


Figure 3. Compressive Strength Test results @ 7 days (0.4 PP Fibers)

Table 3. Compressive Strength Test results @ 28 days (0.4 PP Fibers)

Mix (0.4 PP Fibers)	28 days strength		Average	
	Psi	MPa	Psi	MPa
PC	3042.89	27.98	3932.69	27.115
	3082.05	26.25		
FC1	4359.83	30.06	4355.48	30.03
	4351.13	30.00		
FC2	5304.03	36.57	5299.67	36.54
	5295.32	36.51		
FC3	4890.67	33.72	4903.72	33.81
	4918.22	33.91		

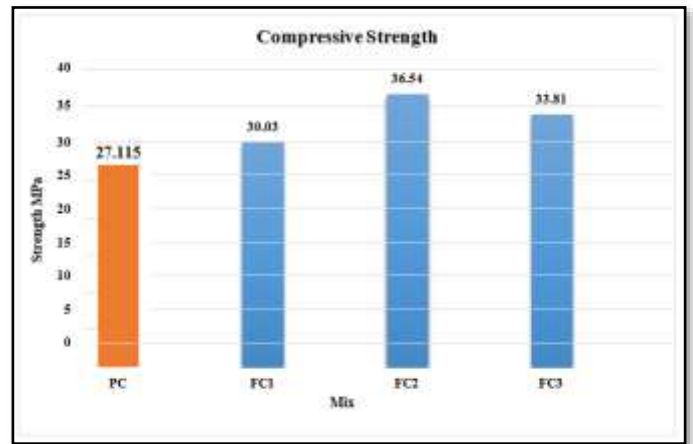


Figure 4. Compressive Strength Test results @ 28 days (0.4 PP Fibers)



Figure 5. PC Mix Cylinders after Compressive Test



Figure 6. FC Mix Cylinders after Compressive Test

Table 4. Flexure Strength Test results @ 28 days (0.4 PP Fibers)

Mix (0.4 PP Fibers)	28 days strength		Average	
	Psi	MPa	Psi	MPa
PC	509.44	3.51	504.54	3.47
	499.65	3.44		
FC1	720.08	4.96	709.23	4.89
	700.5	4.82		
FC2	852.35	5.87	844.11	5.82
	837.65	5.77		
FC3	734.78	5.06	736.79	5.08
	739.7	5.10		

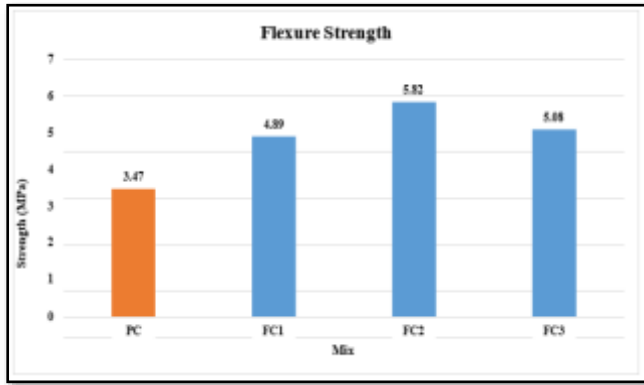


Figure 7. Flexure Strength Test results @ 28 days (0.4 PP Fibers)



Figure 8. PC Mix Beam after Flexure Test



Figure 9. FC Mix Beam after Flexure Test

Table 5. Split Tensile Strength Test results @ 7 days (0.4 PP Fibers)

Mix (0.4 PP Fibers)	7 days strength		Average	
	Psi	MPa	Psi	MPa
PC	160.84	1.109	160.12	1.104
	159.54	1.10		
FC1	261.06	1.80	258.89	1.785
	256.71	1.77		
FC2	288.62	1.99	283.54	1.955
	278.47	1.92		
FC3	259.61	1.79	261.06	1.80
	262.51	1.81		

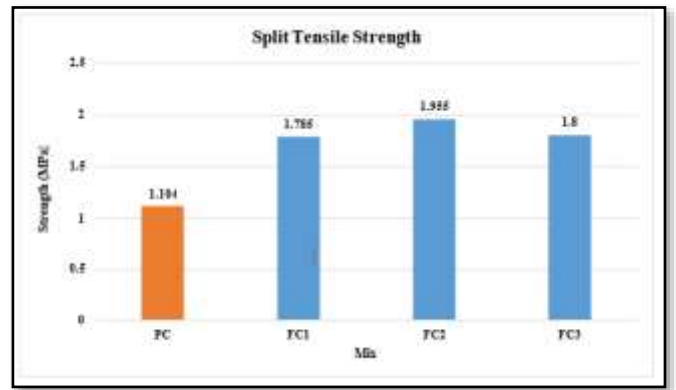


Figure 10. Split Tensile Strength Test results @ 7 days (0.4 PP Fibers)

Table 6. Split Tensile Strength Test results @ 28 days (0.4 PP Fibers)

Mix (0.4 PP Fibers)	28 days strength		Average	
	Psi	MPa	Psi	MPa
PC	364.04	2.51	368.39	2.54
	372.72	2.57		
FC1	459.76	3.17	468.47	3.23
	477.17	3.29		
FC2	613.91	4.23	603.35	4.16
	594.10	4.09		
FC3	495.28	3.41	484.42	3.34
	477.08	3.28		

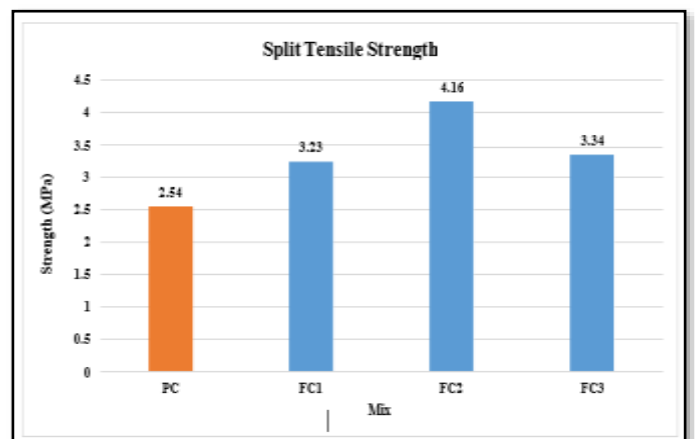


Figure 11. Split Tensile Strength Test results @ 28 days (0.4 PP Fibers)

#### 4.1. Comparison and Analysis of Results:

##### Compressive Strength Test Results:

The results show increase in compressive strength of FC mix as compared to PC. This is not due to addition of PP

Fibers, but because of Silica Fumes in fiber mix. Addition of greater proportion of fibers reduces the compressive strength to some extent. This observation seems to indicate that there may be an effective volume threshold, adversely affecting the compressive strength of concrete due to fiber addition. Higher dosage of PP fibers decreases the strength of concrete matrix due to higher volume of fibers interfering with the cohesiveness of the concrete matrix. But Silica fumes effectively play its role in increasing the strength. Same pattern of increment of strength was observed in both 7- & 28-days strength. Maximum compressive strength was observed in FC2 (0.4 PP fibers and 10% silica fumes) @ 28 days with an increase of about 41% as compared to PC mix.

#### ***Flexure Strength Test Results:***

Results show that flexure strength increases with the addition of PP fibers and then decreases at higher dosage and it can be clearly seen in the results section. This behavior is due to the bonding problems of concrete aggregates. Maximum value of flexure strength is observed in FC mix (0.4 PP fibers and 10% silica fumes) @ 28 days with the increase of about 68% as compared to PC mix. The behavior of FC mix was again ductile and it showed a crack around the beam periphery while PC mix beam broken into two halves after the performance of flexure strength test.

#### ***Split Tensile Test Results:***

Results show that tensile strength becomes high by the addition of Polypropylene fibers and then decreases at higher dosage. Maximum value of tensile strength is observed in FC2 mix (0.4 PP fibers and 10% silica fumes) @ 28 days with the increase of about 64% compared to PC mix. FC mix samples showed more elastic behavior. Tensile strength is increased due to bridging mechanism of Polypropylene fibers. After maximum strength gain it reduces the bond strength between concrete ingredients so result in quick failure.

## **5. Conclusions and Recommendations**

### ***Conclusions:***

Based on a strenuous research work and various studies carried by our syndicate, it revealed that the use of PP Fibers and Silica fumes in any concrete structure enhances many of its mechanical properties. The methodology and the work carried out by our syndicate showed remarkable results of the concrete.

- Various tests were performed in laboratory on properties of concrete and remarkable increase in properties of concrete was observed.
  - Compressive Strength (41% increase)
  - Flexure Strength (68% increase)
  - Split Tensile Strength (64% increase)
- Silica fumes in concrete helped it to become denser and more durable.
- The fibers are found to be an excellent material for enhancement of flexibility, a property which induces into the concrete member soon after it comes in contact. It develops a strong matrix holding the concrete elements intact.
  - The FC samples were more flexible and after performance of tests it can be clearly observed that after loading it can show more deflection than compared to the PC samples.
- The FC samples also indicated its safe and long-lasting use even after such loading.
- PP fibers and Silica fumes help to enhance such properties which helps concrete to withstand larger loads.

### ***Recommendations***

- Duration the execution phase of the research works some gray areas have been identified, which require consideration for the future research work, these are:
- The use of Polypropylene Fibers and Silica fumes should be encouraging in Civil Engineering Industry

due to the added properties it provides to the concrete.

- Study should be carried out and these added properties of concrete should be taken into consideration for reducing the concrete member depth/thickness and /or steel reinforcement.
- Long term strength development of concrete due to addition of Silica fumes, on and beyond 56 days should be studied.
- PP Fibers are available in different lengths. Different aspect ratio of PP Fibers should be used in concrete and its properties should be considered in the research.

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