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Effect of Pozzolanas on Fibre Reinforced Concrete

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Abstract: India generates more than 88 million tons of fly ash annually, predominantly of Class F type, with a meager utilization rate of approximately 10 to 15%. To enhance its utilization, an extensive investigation was conducted to explore its incorporation in concrete. This article presents the outcomes of an experimental study involving concrete with elevated proportions of Class F fly ash. Portland cement was substituted with three different percentages (40%, 45%, and 50%) of Class F fly ash. Tests were conducted to assess fresh concrete properties, including slump, air content, unit weight, and temperature. Compressive, splitting tensile, and flexural strengths were measured over a 28-day testing period. The results indicated that incorporating high volumes of Class F fly ash as a partial replacement for cement led to a reduction in the 28-day compressive and flexural strengths of the concrete. Nevertheless, based on the findings, it was concluded that Class F fly ash can be effectively utilized up to a 50% level of cement replacement in concrete, particularly for precast elements and reinforced cement concrete construction.

Keywords: Class F fly ash, Fly ash utilization, High volume fly ash concrete.

I. Introduction

Concrete, a widely used man-made construction material globally, is formulated by combining cementitious materials, water, aggregate, and occasionally admixtures in specific proportions. In its initial state, referred to as plastic concrete, it can be molded into various shapes and eventually solidifies into a rock-like mass known as concrete [1]. The solidification process results from a chemical reaction between water and cement, evolving over an extended period, contributing to increased strength over time.

The extensive utilization of concrete in the first half of the previous century, employing ordinary Portland cement (OPC) and plain round mild steel bars, fostered a complacent attitude. This neglect for durability, combined with the ease of obtaining constituent materials, resulted in a deterioration in the quality of concrete structures [2]. This decline accelerated after 1970, coinciding with the increased use of high-strength rebars with surface deformations (HSD), alterations in cement properties, and the inclusion of supplementary cementitious materials and admixtures without adequate consideration.

The detrimental impact on the health of newly constructed concrete structures stands as direct evidence of the service life performance challenges. The degradation of infrastructure globally, especially when exposed to real environments, presents an alarming and unacceptable trend.

Ordinary Portland Cement (OPC), a crucial component in concrete production, lacks a substitute in civil construction. However, cement production significantly contributes to carbon dioxide emissions, exacerbating environmental concerns. This mandates the exploration of alternative or supplementary materials to achieve global sustainable development and minimize environmental impact.

Various pozzolanic materials like fly ash, ground granulated blast furnace slag, rice husk ash, high reactive metakaolin, and silica fume offer potential as partial replacements for cement in concrete [3]. Ongoing studies, both in India and abroad, assess the impact of incorporating these materials, showing promising results [4, 5]. Concrete properties, including strength and durability, are influenced by ingredient properties, mix proportions, compaction methods, and controls during placement and curing.

In the pursuit of high-strength and durable concrete, the construction industry has witnessed the emergence of high-performance concrete (HPC) over the last 35 years. HPC aims to achieve compressive strengths ranging from M60 to M120 and even higher in laboratory conditions. Prestressed concrete technology has further propelled the development of high-strength concrete [6, 7]. However, concerns about the durability of structures using these materials necessitate careful consideration.

The term “High-Performance Concrete” encompasses concrete meeting specific performance and uniformity requirements beyond the capabilities of conventional constituents and practices. ACI defines critical characteristics for HPC applications, including ease of placement, compaction without segregation, early age strength, long-term mechanical

properties, permeability, density, heat of hydration, toughness, volume stability, and resilience in severe environments [8]. Achieving these characteristics often involves a combination of mineral and chemical admixtures.

Salient features of HPC include high compressive strength, low water-binder ratio, reduced cement grain flocculation, a wide range of grain sizes, densified cement paste, homogeneous mix with no bleeding, less capillary porosity, and discontinuous pores.

The demand for high-strength concrete arises from the need for earlier serviceability, reduced column sizes, and increased space in high-rise buildings, as well as for the superstructures of long-span bridges and durable bridge decks. Special methods such as seeding, revibration, high-speed slurry mixing, use of admixtures, crack inhibition, sulfur impregnation, and the use of cementitious aggregates are employed in producing high-strength concrete [9, 10].

As the construction industry leans towards precast elements and the demand for post-tensioning grows, achieving high-strength concrete becomes imperative. The construction focus on achieving cost savings further underscores the importance of high-strength concrete in the concreting process.

II. Materials Used

A. Cement

Cement is a substance characterized by its cohesive and adhesive qualities when mixed with water, and cements that exhibit these properties are known as hydraulic cements. These hydraulic cements mainly comprise silicates and aluminates of lime, derived from limestone and clay. One common type of hydraulic cement is Ordinary Portland Cement (OPC).

Ordinary Portland Cement (OPC) stands out as the fundamental Portland cement and is particularly well-suited for general concrete construction purposes. OPC is classified into three grades: 33 grade, 43 grade, and 53 grade, each denoting different compressive strengths. One notable advantage of OPC is its rapid rate of strength development, making it a preferred choice for various construction applications.

B. Rice Husk Ash

Rice husk ash is a by-product obtained by burning rice husk under controlled conditions, ensuring minimal environmental impact. When properly burned, it contains a high concentration of SiO_2 and can be utilized as a concrete admixture. Rice husk ash demonstrates pronounced pozzolanic properties, contributing significantly to the strength and impermeability of concrete.

The composition of rice husk ash primarily comprises amorphous or non-crystalline silica, with approximately 85-90% of cellular particles, 5% carbon, and 2% K_2O. The specific surface area of rice husk ash ranges between 40,000 to 100,000 m^2/kg. This unique combination of elements makes rice husk ash a valuable additive in concrete formulations, enhancing its performance and durability. Table I gives the description about chemical composition of RHA.

Table I: Chemical Properties of RHA

Chemical Compounds	Composition (in wt%)
SiO_2	85.88
Al_2O_3	0.47
Fe_2O_3	0.18
CaO	1.12
MgO	0.46
Na_2O	1.15
K_2O	4.10
SO_3	1.24

C. Silica Fume

Silica fume, also known as micro-silica or condensed silica fume, is an artificial pozzolanic admixture employed in construction. It is produced by reducing high purity quartz with coal in an electric arc furnace during the manufacturing of silicon or ferrosilicon alloy. The process involves subjecting quartz to high temperatures, causing reduction and the release of SiO vapors. These vapors undergo oxidation during exit and condense into a non-crystalline state with ultra-fine particle size in low-temperature zones. The resulting silica fume, in oxidized vapor form, is collected through filters, cooled, condensed, and further processed to eliminate impurities and control particle size.

Condensed silica fume is primarily composed of silicon dioxide (SiO_2), exceeding 90 percent in a non-crystalline form. Due to its airborne nature, similar to fly ash, it exhibits a spherical shape. With particle sizes less than 1 micron and an average diameter of about 0.1 micron, silica fume is exceptionally fine, around 100 times smaller than average cement particles. It boasts a specific surface area of about 20,000 m^2/kg, in contrast to 230 to 300 m^2/kg for typical cement. Table II gives the description about chemical composition of Silica fume.

Table II: Chemical Properties of Silica Fume

Chemical Compounds	Composition (in wt%)
SiO_2	93
Al_2O_3	0.4
Fe_2O_3	0.2
CaO	1.2
MgO	1.2
Na_2O	0.1
K_2O	1.1
SO_3	1.3

D. Super Plasticizing Admixture

A substance that imparts exceptionally high workability to concrete while significantly reducing water content (by at least 20%) for a given level of workability is known as a high-range water-reducing admixture (HRWRA) or Superplasticizer. Superplasticizers, capable of reducing water content by approximately 20 to 40 percent, have been developed. These additives can be introduced into concrete mixes with low to normal slump and water-cement ratio to produce flowing concrete with a high slump. The effectiveness of superplasticizers is temporary, lasting for 30 to 60 minutes, dependent on composition and dosage, and is followed by a rapid loss in workability.

The water-cement ratio plays a crucial role in concrete production, influencing capillary pore formation, permeability, and overall durability. Superplasticizers are essential for creating high-performance concrete (HPC) characterized by a low water-cement ratio and workability without the need for excessive cement content. Concrete with remarkably low w/c ratios, such as 0.25 or even 0.20, has been achieved, resulting in highly durable HPC. Workability can also be influenced by the maximum size of aggregate, with larger sizes enhancing workability, while smaller sizes increase compressive strength by providing a larger surface area for bonding with the mortar matrix.

In the study, high-range superplasticizer was uniformly employed in all concrete mixes to ensure optimal workability. The addition of superplasticizers aimed to reduce water requirements by 15 to 20% without compromising workability, resulting in high-strength and dense concrete. Admixture dosage was adjusted to maintain uniform workability without altering the unit water content, ensuring identical water-cement ratios for specific cementitious content. This approach facilitated a direct examination of the impact of pozzolanic material replacement on various concrete properties.

E. Aggregate

Aggregate characteristics play a significant role in influencing the performance of concrete, as they constitute approximately 80% of the total volume of the concrete. Aggregates are broadly classified into two categories:

(a) Fine Aggregate (b) Coarse Aggregate

Fine aggregates are materials that pass through an IS sieve with a gauge size of less than 4.75 mm, beyond which they are termed as coarse aggregates. Coarse aggregates constitute the primary matrix of the concrete, while fine aggregates fill the matrix between the coarse aggregates. The crucial role of fine aggregates is to enhance workability and ensure uniformity in the concrete mixture. Additionally, fine aggregates assist the cement paste in suspending the coarse aggregate particles.

As per the guidelines outlined in IS 383:1970, fine aggregates are classified into four different zones, namely Zone-I, Zone-II, Zone-III, and Zone-IV. Furthermore, for coarse aggregates, a maximum size of 20 mm is recommended for concrete work. However, in situations where no restrictions apply, sizes of 40 mm or larger may be permissible. In cases involving close reinforcement, a 10 mm size is also utilized.

F. Fiber

In recent times, numerous investigations have been carried out to explore methods for enhancing the flexural strength of reinforced concrete (RC) members using fiber-reinforced composite fabrics. The adoption of high-strength fiber-reinforced polymer (FRP) materials as structural reinforcements for concrete has gained widespread acceptance.

This composite material integrates short discrete fibers that are distributed randomly throughout the concrete mass. The performance efficiency of this composite material significantly surpasses that of plain concrete and many other construction materials with comparable costs. This advantage has led to a consistent increase in the utilization of fiber-reinforced concrete (FRC) over the past two decades. Its current applications encompass a broad range, including airport and highway pavements, earthquake-resistant and explosive-resistant structures, mines and tunnel linings, bridge deck overlays, hydraulic structures, and rock slope stabilization.

Comprehensive research in the field of FRC has demonstrated that incorporating various fiber types, such as steel, glass, synthetic, and carbon, into plain concrete enhances its strength, toughness, ductility, and resistance to post-cracking. Key benefits of fiber-reinforced concrete include resistance to micro-cracking, impact resistance, resistance to fatigue, reduced permeability, and improved strength in shear, tension, flexure, and compression.

The characteristics and performance of FRC undergo changes based on varying concrete binder formulations, as well as factors such as fiber material type, fiber geometry, fiber distribution, fiber orientation, and fiber concentration.

G. Recron 3s Polypropylene Fiber

Recron Fiberfill, India's exclusive hollow fiber designed for filling and insulation is crafted with DuPont's technology from the USA. Adhering to international quality standards, Recron Fiberfill ensures maximum comfort, durability, and versatility in applications such as sleep products, garments, and furniture, backed by Reliance Industries Limited (RIL). The launch of Recron 3s fibers by RIL aims to enhance plaster and concrete quality.

The application of Recron 3s fiber-reinforced concrete in construction proves beneficial. In low dosages, the thinner and

stronger elements effectively span the entire section, mitigating cracking [13]. Recron 3s prevents the development of shrinkage cracks during curing, contributing to the inherent strength of structures, plasters, or components.

Moreover, when concrete experiences loads nearing failure, cracks may propagate rapidly. The inclusion of Recron 3s in concrete and plaster effectively prevents and arrests cracking resulting from volume changes, such as expansion and contraction. A concrete structure devoid of micro cracks prevents water or moisture infiltration, safeguarding the primary reinforcement steel from corrosion and thereby enhancing the structure's longevity. Specification of Recron3 polypropylene fiber is tabulated in Table III.

Table III: Specification of Recron3 Polypropylene Fiber

Properties	Results
Appearance	Form: Short-Cut Staple Fiber
Denier	1.5d
Cut length	6 mm,12 mm,24 mm
Tensile strength	About 6000 kg/cm^3
Relative density	0.89 – 0.94 g/cm^3
Dispersion	Excellent
Acid resistance	Excellent
Alkali resistance	Good

Recron 3s exhibits a high modulus of elasticity compared to the concrete or mortar binder, contributing to increased flexural strength. These fibers are environmentally friendly, non-hazardous, and easily disperse and separate in the mix [14]. With a minimal dosage of 0.2-0.4% by concrete, Recron 3s proves sufficient to gain the mentioned advantages. This not only offsets its own cost but results in a net gain by reducing labor costs and improving material properties. In summary, the advantages of Recron 3s fiber include enhanced strength, durability, and environmental friendliness in various construction applications.

III. Testing of Raw Materials

For the experiment type of cement used was Ordinary Portland cement (53 grade). Table IV shows the properties of OPC.

Table IV: Shows the Properties of OPC

Specific Gravity	Initial Setting Time (mm)	Final Setting Time (mm)
3.1	90	190

In this study, sand of Zone-II, known from the sieve analysis using different sieve sizes (10 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600 μ, 300 μ, 150 μ) adopting IS 383:1963. Table V shows the properties of fine aggregate.

Table V: Properties of Fine Aggregate

Specific Gravity	Water Absorption	Fineness Modulus
2.65	0.6%	2.47

The coarse aggregate used here with having maximum size is 20 mm. We used the IS 383:1970 to find out the proportion of mix of coarse aggregate, with 60% 10 mm size and 40% 20 mm. Table VI shows the properties of coarse aggregate.

Table VI: Properties of Coarse Aggregate

Specific Gravity	Water Absorption	Fineness Modulus
2.67	0.4%	4.01

In this project, Recron 3s fiber, a synthetic fiber, was incorporated into the concrete at different weight fractions (0.0%, 0.1%, 0.2%, 0.3%). Rice husk ash (RHA) used in this study exhibited a white color due to being burnt at a higher temperature, resulting in lower carbon percentages, which positively impact strength development. The specific gravity of RHA, determined using the Le-Chatelier apparatus, was found to be 2.20.

Silica fume, known for its enhanced pozzolanic activity, was introduced in various percentages (0%, 10%, 20%, 30%) as a replacement for cement in conjunction with fiber. The specific gravity of silica fume was determined to be 2.36 using the Le-Chatelier apparatus.

The determination of normal or standard consistency involves establishing the quantity of water required to create a standard cement paste capable of withstanding a specified pressure. It signifies the water threshold necessary for the cement paste to resist the penetration of a standard plunger (1 mm diameter) under a specific load, up to a distance of 5-7 mm from the base of Vicat's apparatus. The consistency of cement is influenced by its type and fineness, with higher fineness values requiring more water. The water quantity was calculated using the formula [(P/4) + 3]% of 800 gm, where P represents the pressure. Consistency tests were conducted with different percentages of Silica Fume (SF) and Rice Husk Ash (RHA), specifically SF at 0%, 10%, 20%, 30%, 40%, and RHA at 0%, 10%, 20%, 30%. Subsequently, mortars of standard size were cast with varying percentages of SF (0%, 10%, 20%, 30%, 40%) and RHA (0% and 20%) as replacements for cement. Portland slag cement and sand of Zone-II were employed in this experimental setup. Table VIII illustrates the effect of RHA on the normal consistency of OPC, and Fig. 1 depicts the variation in the consistency of cement with different percentages of RHA.

Table VII: Effect of RHA on Normal Consistency of OPC

% of Cement Replaced by RHA	Consistency (%)
0	31.0
10	45.0
20	48.0
30	52.0

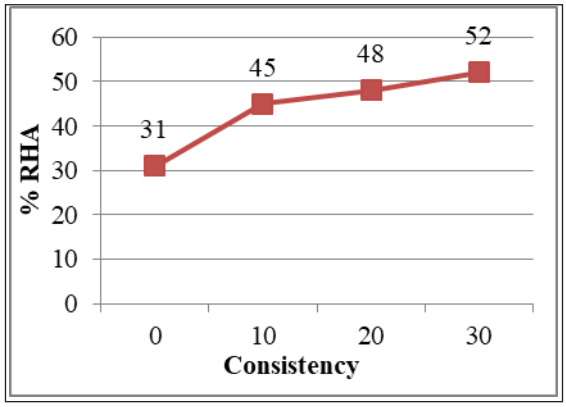


Fig. 1: Variation in Consistency of Cement with Different % of RHA

Compression tests were then carried out on the mortars using a Compression Testing Machine after curing for 7 days and 28days. The Compressive strength test results are tabulated in Table VIII and their variations are depicted in Fig. 2.

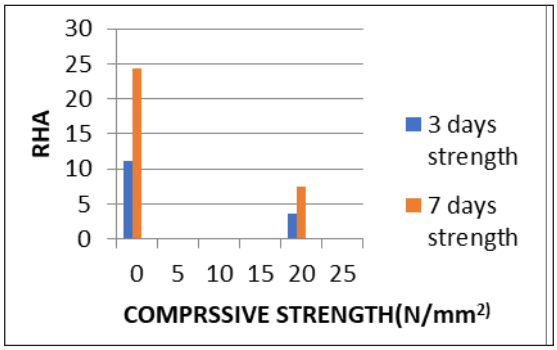


Fig. 2: Variation in Compressive Strength of Mortar with Use of RHA

Table VIII: Effect of RHA on Compressive Strength of OPC

% of Cement Replaced by RHA	3 Days Strength (MPa)	7 Days Strength (MPa)
0	11.176	24.31
20	3.65	7.45

Similarly, the effect of silica fume on normal consistency of OPC is carried out. Table IX shows the effect of Silica fume on normal consistency of OPC. Fig. 3 shows the variation in Consistency of Cement with different % of Silica fume.

Table IX: Effect of Silica Fume on Normal Consistency of OPC

% of Cement Replaced by Silica Fume	Normal Consistency (%)
0	31.0
10	38.0
20	41.5
30	45.0

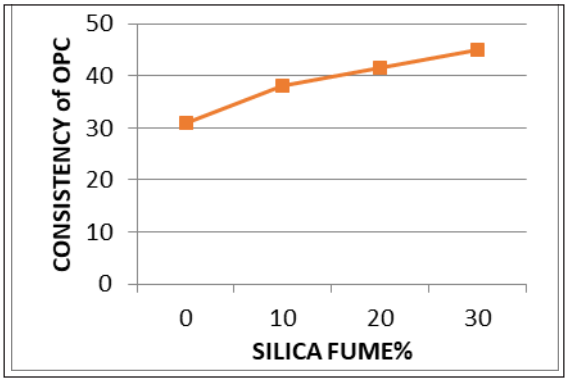


Fig. 3: Variation in Consistency of Cement with Different % of Silica Fume

The compressive strength of their mortar cubes after being cured for 7 days and 28 days is tested, and their results are tabulated in Table X. The Fig. 4 shows the variation of compressive strength with the effect of silica fume addition.

Table X: Effect of RHA on Compressive Strength of OPC

% of Cement Replaced by SF	3 Days Strength (MPa)	7 Days Strength (MPa)
0	11.176	24.31
10	9.66	15.63
20	10.55	17.65
30	8.10	9.15
40	6.74	7.46

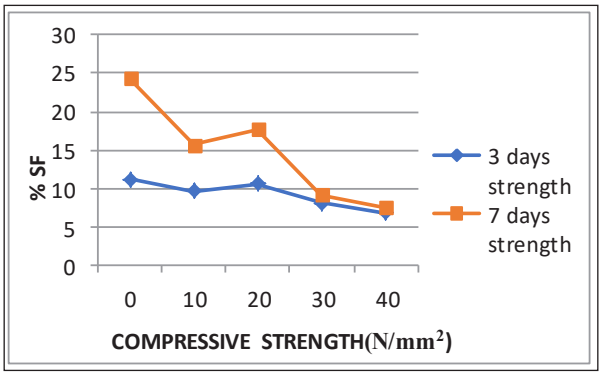


Fig. 4: Variation in Compressive Strength of Mortar with Use of SF

The analysis indicates a gradual rise in the consistency percentage as the proportion of Silica Fume (SF) replaces cement, although the change is not abrupt. In contrast, a noteworthy observation is the swift increase in consistency percentage with a higher percentage of Rice Husk Ash (RHA). Examining the variation in compressive strength among mortar mixes with different SF partial replacement proportions, the figure illustrates that the 3-day and 7-day compressive strength experiences an approximate 10% and 20% increment, respectively, moving from 9.66 MPa to 10.55 MPa and 15.63 MPa to 17.65 MPa as the SF percentage increases from 0 to 20%. However, further elevating the SF percentage results in a decline in compressive strength. Specifically, when the SF percentage reaches 40%, the strength decreases by around 60% and 70% in 3 days and 7 days, respectively, compared to the initial values. This leads to the conclusion that the utilization of SF, particularly in Ordinary Portland Cement, adversely affects the mortar's strength.

Furthermore, utilizing Rice Husk Ash (RHA) as a partial replacement for cement does not produce satisfactory strength. Despite the white type of RHA exhibiting better strength compared to low-burned RHA, the compressive strength of mortar mixes with varying SF proportions as a partial replacement for cement demonstrates superior strength compared to RHA as a partial replacement for cement. Consequently, concrete specimens were tested with different proportions of SF as a partial replacement for Ordinary Portland Cement and Recron 3s fiber in relation to the weight of concrete.

IV. Mix Proportioning of Recron-Fiber Reinforced Concrete

To develop Recron fiber reinforced concrete and to study the effect of silica fume keeping fiber percentage constant concrete specimen were casted. For this purpose it was used types of cement called ordinary Portland cement (53grade). Coarse aggregates with a maximum size of 20 mm and sand classified as Zone-II were utilized in the study. In the case of fiber-reinforced concrete, varying percentages (0%, 0.1%, 0.2%, 0.3%) of Recron fiber, relative to the weight of concrete, were incorporated. Subsequently, the percentages of silica fume were altered (0%, 10%, 20%, 30%), while keeping the fiber content constant, to investigate the impact of silica fume. A consistent slump range of 50-75mm was maintained to ensure proper workability for easy handling and placement in all instances. Sika admixture was employed to uphold this slump, maintaining water-cement ratios within the ranges of 0.35-0.41 and 0.41-0.45. Superplasticizer was applied in the ranges of 0.6%-1.4% and 1.4%-1.7% for ordinary fiber-reinforced concrete and fiber-reinforced polymer (FRP) with the addition of silica fume, respectively. The aggregate binder ratio was 3.08, and the coarse aggregate to fine aggregate ratio was 2.34.

In the case of Ordinary Portland Cement (OPC), a mix with a water-cement ratio of 0.38 and 0.8% admixture was obtained for normal concrete. Subsequently, mixes were created with varying percentages of silica fume (10%, 20%, and 30%), maintaining a constant 0.2% fiber content, and adjusting water-cement ratios (0.422, 0.44, and 0.46) and admixture (1.4%, 1.6%, and 1.7%).

All mixtures underwent mixing in a conventional rotary drum concrete mixer. The process involved loading the mixer with coarse aggregate and a portion of the mixing water, followed by the addition of sand, cement, and the remaining water, mixed for 3 minutes. In fibrous mixtures, the fibers were randomly distributed. The Sika admixture was added to the mixing water, and in the case of (cement + silica fume), it was added simultaneously with the cement. The resulting concrete was cast, vibrated using a vibrating machine, and molded into cubes, cylinders, and prisms of dimensions 150 mm cubes, cylinders with a height of 300 mm and diameter of 150 mm, and prisms with a length of 500 mm, height of 300 mm, and breadth of 100 mm each. All specimens were demolded after 24 hours and subsequently cured for 7 and 28 days. Compressive strength and flexural strength were assessed on cubes and prisms, respectively, following Indian standard codes (IS 456:2000, IS 5816:1999, IS 561:1959, IS 9399-1979, and IS 10262-1982). Fig. 5 and 6 depict the compressive strength and flexural strength tests on concrete cubes and prisms, respectively.



Fig. 5: Compressive Strength Test on Concrete Cube After 7 and 28 Days of Curing



Fig. 6: Flexural Strength Test on Concrete Prism After 7 and 28 Days of Curing

V. Results and Discussions

The consistency of cement is contingent upon its fineness. Due to its finer particles and increased surface area compared to cement, silica fume significantly augments consistency. It was noted that the normal consistency experiences a substantial 45% increase as the percentage of silica fume rises from 0% to 20% in comparison to plain cement.

The compressive strength of concrete cubes and the effect of silica fume at 0.2% fiber and OPC are tested after 7 days and 28 days of curing. Their results are tabulated in Table XI and their variation is depicted in Fig. 7.

Table XI: Effect of Silica Fume on Compressive Strength using OPC

Silica Fume (%)	7 Days Compressive Strength (N/mm^2)	28 Days Compressive Strength (N/mm^2)
0.0(0.2% Fibre)	29.00	35.33
10.0(0.2% Fibre)	29.50	36.00
20.0(0.2% Fibre)	32.00	38.28
30.0(0.2% Fibre)	34.50	42.32

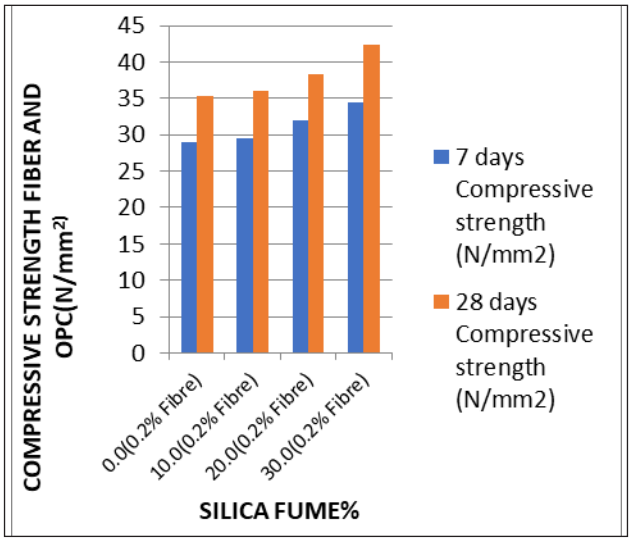


Fig. 7: Effect of Silica Fume on Compressive Strength at 0.2% Fiber and OPC

Concerning Ordinary Portland Cement (OPC), it was observed that incorporating Recron fiber in the range of 0.0% to 0.1% resulted in a slight enhancement in compressive strength. However, as the fiber percentage increased from 0.1% to 0.2%, there was further improvement in compressive strength. Subsequent increments in fiber content, however, led to a reduction in strength. The 28-day compressive strength of the concrete was highest with 0.2% fiber compared to other fiber compositions but lower than unreinforced concrete. Silica fume was introduced in conjunction with the fiber as a partial replacement for cement. Various percentages of silica fume (10%, 20%, and 30% replacement) were used alongside 0.2% Recron fiber. The highest strength was achieved with a 20% replacement of Ordinary Portland cement with silica fume compared to other replacement percentages.

In the context of Portland slag cement, the addition of Recron fiber from 0.0% to 0.1% resulted in a marginal increase in splitting tensile strength. However, with an increase in fiber percentage, particularly at 0.2%, the 28-day splitting tensile strength exhibited an improvement of about 5% compared to concrete without fiber. Further increments in fiber content led to a reduction in strength. When 20% silica fume was used as a replacement for cement alongside 0.2% fiber content, the strength increased by approximately 12% compared to normal concrete, surpassing other replacement percentages. The flexural strength of concrete prisms and the effect of silica fume at 0.2% fiber and OPC are tested after 7 days and 28 days of curing. Their results are tabulated in Table XII and their variation is depicted in Fig. 8.

Table XII: Effect of Silica Fume on Flexural Strength using OPC

Silica Fume (%)	7 Days Flexural Strength (N/mm^2)	28 Days Flexural Strength (N/mm^2)
0.0(0.2% Fibre)	9.50	11.125
10.0(0.2% Fibre)	7.875	9.00
20.0(0.2% Fibre)	6.75	8.25
30.0(0.2% Fibre)	6.04	6.875

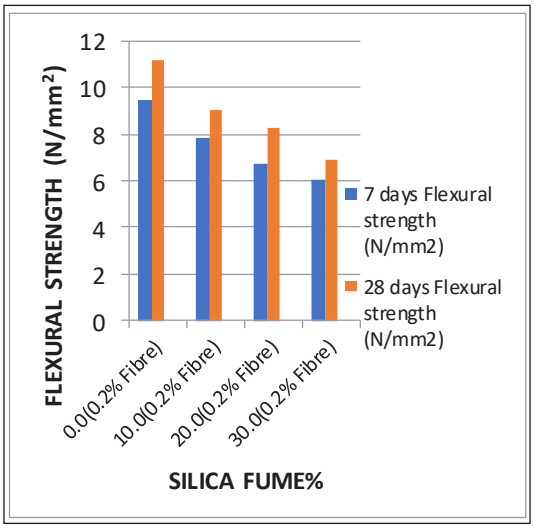


Fig. 8: Effect of Silica Fume on Flexural Strength at 0.2% Fiber and OPC

The flexural strength undergoes a decline when incorporating Recron fiber in proportions ranging from 0.0% to 0.1%. However, an escalation in fiber percentage from 0.1% to 0.2% results in a notable 5% improvement in flexural strength. Subsequent increments in fiber content, however, lead to a subsequent decrease in strength. In instances where silica fume replaces cement at a 0.2% fiber content, positive outcomes are

observed in flexural strength. At 20% silica fume replacement, there is a notably higher strength, approximately 10% more than normal concrete, marking it as the maximum strength among other percentages of silica fume replacement.

For Ordinary Portland cement, maintaining a 0.2% fiber content and varying silica fume percentages (10%, 20%, 30%), it was noted that the 28-day flexural strength decreases with an increase in silica fume percentage. The strength experiences a reduction of approximately 40% at 30% silica fume replacement compared to normal concrete.

VI. Conclusion

In this investigation, within the designated timeframe and laboratory setup, an effort has been made to shed light on the utilization of pozzolanic materials such as ground granulated blast furnace slag, rice husk ash, and silica fume in fiber-reinforced concrete, assessing their effectiveness. The findings can be summarized as follows:

- Replacement of cement with rice husk ash (RHA) leads to an increase in consistency. Properly burned RHA at controlled temperatures enhances the strength of mortar, while unsatisfactory results are obtained when using inadequately processed RHA.
- The use of superplasticizer allows for achieving a mix with a low water-to-cement ratio, facilitating the attainment of desired strength.
- Consistency increases with the progressive replacement of cement with varying percentages of silica fume.
- The optimal combination for achieving desired outcomes is identified as 0.2% Recron fiber and 20% silica fume.
- In the case of Ordinary Portland Cement (OPC), compressive strength increases with the percentage of silica fume ranging from 0% to 30%, accompanied by 0.2% Recron fiber, exhibiting approximately 20% higher strength than normal concrete with OPC.
- Splitting tensile strength experiences a 15% increase at 10% silica fume content, maintaining a constant 0.2% Recron fiber, followed by a decrease with higher silica fume percentages. Flexural strength exhibits a decreasing trend, with a significant 40% decrement as the silica fume percentage reaches 30%.
- Ordinary Portland Cement demonstrates superior compressive strength results compared to Portland slag cement in mixes with silica fume and 0.2% Recron fiber.

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