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# Impact of Pozzolanic Materials on Strength and Durability of Fiber Reinforced Concrete - An Experimental Study

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***Abstract*** **- The present study investigates the effect of pozzolanic materials on the mechanical and durability properties of Fiber reinforced concrete. The research evaluates the performance of concrete incorporating Silica Fume (SF), Rice Husk Ash (RHA), and Ground Granulated Blast Furnace Slag (GGBS) along with Recron synthetic fibres. Experimental investigations were carried out to determine compressive strength, split tensile strength, flexural strength, porosity, and capillary water absorption characteristics. Different replacement levels of pozzolanic materials and Fiber contents were considered to identify the optimum mix proportion. The results revealed that the incorporation of Recron fibres significantly enhanced the tensile and flexural behaviour of concrete, while Silica Fume contributed to substantial improvements in strength and durability. The optimum performance was achieved with 20% Silica Fume and 0.2% Recron Fiber, which exhibited superior mechanical properties and reduced porosity and capillary absorption compared to conventional concrete. The study concludes that the combined use of Silica Fume and Recron fibres can be effectively utilized for producing durable and high-performance concrete suitable for modern construction applications.**

***Keywords - Fiber Reinforced Concrete, Silica Fume, Rice Husk Ash, GGBS, Recron Fiber, Compressive Strength, Durability, Pozzolanic Materials.***

## I. INTRODUCTION

Concrete is the most widely used construction material; however, its brittle nature and low tensile strength remain major limitations. Pozzolanic materials such as Silica Fume, RHA, and GGBS have been extensively used to enhance concrete performance. The incorporation of synthetic fibers further improves crack resistance and ductility. This study evaluates the combined effect of pozzolanic materials and Recron fibers on concrete properties.

Concrete plays a significant role in modern civil engineering because of its strength, durability, mouldability, and economic advantages. It is widely used in residential buildings, bridges, industrial structures, pavements, and other infrastructure. Despite these advantages, conventional concrete has certain limitations, particularly its low tensile strength, brittle behaviors, and susceptibility to cracking. The development of fiber-reinforced concrete has provided an approach to improving crack resistance and post-cracking behavior. Fibers distributed throughout the concrete matrix can bridge developing cracks and influence tensile and flexural performance. The effectiveness of fiber reinforcement depends on the type of fiber, fiber length, aspect ratio, volume fraction, bond characteristics, and dispersion during mixing.

Rice husk ash is obtained from the controlled burning and processing of rice husks, an agricultural by-product. When suitably produced, RHA can contain reactive silica and may be used as a supplementary cementitious material. Its use can also provide a productive application for agricultural waste. However, its performance depends on the burning process, fineness, carbon content, and chemical composition.

Silica fume is a finely divided, silica-rich material commonly used in high-performance concrete. Its fine particles can improve particle packing, while its pozzolanic reaction can contribute to the formation of additional cementitious products. Nevertheless, silica fume can increase water demand and requires appropriate mix design and workability control.

The combined incorporation of fibers, RHA, and SF may influence the strength, cracking behavior, and durability of concrete. However, the resulting performance depends on the proportions and properties of the constituent materials.



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Therefore, an experimental investigation is required to evaluate these effects under controlled laboratory conditions.

**Rice Husk Ash in Concrete**

Rice husk ash has been investigated as a supplementary cementitious material because properly processed ash may contain reactive silica. Its incorporation can influence cement hydration, pore structure, workability, and strength development. The degree of improvement depends on the replacement level, fineness, burning conditions, and curing regime. Excessive replacement may reduce strength if the ash has low reactivity or if insufficient cementitious material remains in the mixture. Therefore, the optimum RHA content must be determined experimentally for the specific materials used.

**Silica Fume in Concrete**

Silica fume is widely used in high-performance concrete because of its fine particle size and pozzolanic activity. It can improve the density of the cementitious matrix and reduce the connectivity of pores when an appropriate mixture design is used. These characteristics may contribute to improved strength and resistance to the ingress of certain aggressive substances. However, silica fume may reduce workability because of its high surface area. Appropriate water-to-binder ratios, mixing procedures, and compatible chemical admixtures should therefore be considered.

**Fiber-Reinforced Concrete**

Fibers are incorporated into concrete to influence crack development and post-cracking behaviors. Different fibers, including steel, glass, and polypropylene, have different mechanical properties and bond characteristics. Their performance cannot be assumed to be identical. The addition of fibers may improve splitting tensile or flexural behaviors, depending on the fiber system. The effect on compressive strength may be positive, neutral, or negative depending on fiber dosage, dispersion, and the resulting concrete porosity.

**Combined Use of RHA, SF, and Fibers**

Previous studies have examined the use of RHA in high-performance fiber-reinforced concrete and the replacement of a portion of silica fume with RHA. Other investigations have considered glass-fiber concrete containing RHA and silica fume. These studies provide a basis for examining the combined effects of supplementary cementitious materials and fibers. Nevertheless, findings from one study may not apply directly to another because the fiber type, aggregate characteristics, replacement levels, and curing conditions may differ.

## II. OBJECTIVE

- *To evaluate the effect of Silica Fume, RHA, and GGBS on concrete strength.*
- *To study the influence of Recron Fiber on mechanical properties.*
- *To assess durability through capillary absorption tests.*
- *To determine the optimum replacement level of pozzolanic materials*

## III. MATERIAL AND METHODOLOGY

- **Materials**
- **Portland Slag Cement-** Portland Slag Cement (PSC) is a blended eco-friendly cement made by intergrinding or blending Ordinary Portland Cement (OPC) clinker, gypsum, and 25% to 70% Ground Granulated Blast Furnace Slag (GGBS)—a non-metallic industrial byproduct of iron smelting. In India, it is standardized under IS 455:2015.
- **Fine Aggregate-** Fine Aggregate consists of small, granular material primarily sand and crushed stone with a particle size that passes through a 4.75 mm IS sieve (typically ranging down to about 0.075 mm or 150 microns)
- **Coarse Aggregate-** Coarse aggregate refers to larger stone, gravel, or crushed rock particles—typically retained on a 4.75 mm sieve that form the main structural skeleton of concrete, asphalt, and road bases.
- **Water-** Water is a crucial ingredient in cement concrete because it triggers a chemical process called hydration, which binds sand and aggregates into a hard, solid structure
- **Silica Fume-** Silica fume (also known as microsilica) is an ultra-fine, non-crystalline powder collected as a by-product during the industrial production of silicon metal or ferrosilicon alloys in electric arc furnaces.

  **Key Properties**

  i. Composition: Contains 85% to 99% amorphous silicon dioxide ($SiO_2$).
  ii. Particle Size: Average particle diameter is about 0.1 to 0.15 micrometers (~150 nm), making it roughly 100 times smaller than average cement particles.
  iii. Surface Area**:** Extremely high specific surface area, typically ranging from 15,000 to 30,000 $m^2/kg$.
- **Rice Husk Ash (RHA)-** Rice husk ash (RHA) is a fine, gray-to-black powder created by burning the hard protective coverings (husks) of rice grains. Because it is packed with high amounts of silica, it has become a valuable industrial and agricultural material.

  **Key Properties**

  i. Silica Content: Comprises roughly 80% to 95% silica ($SiO_2$).
  ii. Fineness: Often ground into micro-fine particles smaller than cement to boost surface reactivity.
  iii. Industrial Uses: Utilized as a thermal insulating powder in steel casting, a precursor for green silica and sodium silicate, and a component in lightweight bricks or geopolymer matrices.
- **GGBS-** Ground Granulated Blast-Furnace Slag is a fine, off-white powder produced by rapidly quenching and grinding molten iron slag—a industrial by-product of iron and steel manufacturing. It is widely used as a partial or supplementary replacement for Ordinary Portland Cement (OPC) in concrete and construction.



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**Key Characteristics & Composition**

i. Composition: Primarily consists of calcium oxide (~40%), silica (~35%), alumina (~13%), and magnesia (~8%).
ii. Latent Hydraulic Binder: It reacts slowly on its own with water, but forms strength-enhancing calcium silicate hydrate (C-S-H) gel when activated by the calcium hydroxide released during OPC hydration.
iii. Replacement Rate: Typically replaces 25% to 70% (and up to 85% in specific mixes) of standard Portland cement.

- **Recron Fiber-** Recron fiber most notably Recron 3S is a specialized synthetic micro-fiber manufactured by Reliance Industries Limited designed as secondary reinforcement for concrete, mortar, and plaster.

**Key Features & Benefits**

i. Crack Control: Acts as a secondary reinforcement to inhibit plastic and drying shrinkage cracks, reducing overall crack area.
ii. Triangular Cross-Section: Features an engineered shape that improves bonding and mechanical interlock with the cement matrix.

*A. Experimental Program*

Concrete specimens were cast with different percentages of pozzolanic materials and Recron fibers. Standard curing procedures were adopted. Tests performed included:

- Compressive Strength Test
- Split Tensile Strength Test
- Flexural Strength Test
- Capillary Absorption Test

## IV. RESULT

*A. Capillary Absorption Test:* The capillary water absorption behavior of concrete mixes incorporating 0.2% fiber and varying percentages of silica fume (10%, 20%, and 30%) is illustrated in Figure 4.1. The test was conducted to evaluate the pore connectivity and durability performance of the modified concrete mixes.

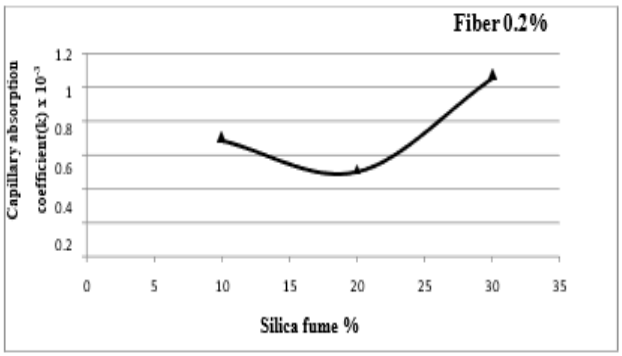



**Fig (1)- Capillary Absorption coefficient of different Silica Fume content**

*B. Flexural Strength Test:* The flexural strength results of Portland slag cement concrete incorporating 0.2% fiber with varying percentages of silica fume (0%, 10%, 20%, and 30%) at 7 and 28 days of curing are illustrated in the figure above. The test results indicate that 20% silica fume replacement combined with 0.2% fiber is the optimum dosage to achieve maximum flexural strength in slag cement concrete.

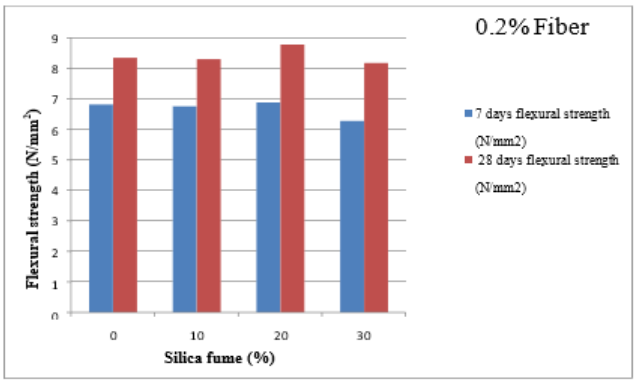



**Fig (2)- Effect of Silica fume on flexural strength at 0.2% Fiber with slag cement**

*C. Split Tensile Strength Test:* The split tensile strength test was conducted on cylindrical specimens using Portland Slag Cement (PSC) to evaluate the influence of Recron fiber addition at curing ages of 7 days and 28 days. The fiber percentages varied from 0.00% (control mix) to 0.30% by volume, and the results are illustrated in the graph above.

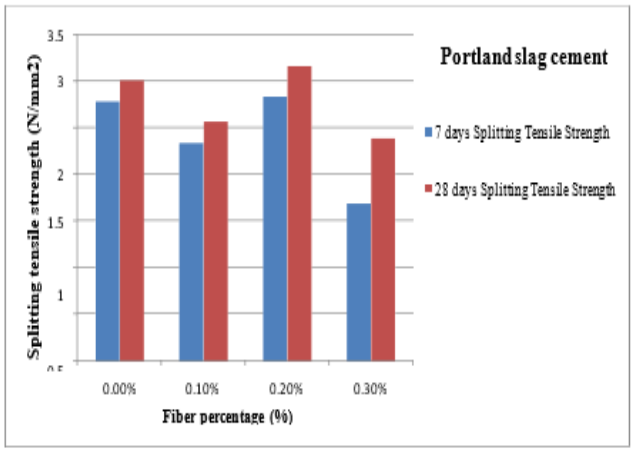



**Fig (3)- Effect of Recron Fiber on Splitting Tensile Strength**



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*D. Compressive Strength Test:* The compressive strength of Portland slag concrete with varying Recron fiber dosages (0.00%, 0.10%, 0.20%, and 0.30%) was evaluated at 7 and 28 days. While the control mix (0.00%) showed the highest baseline strength (38.0 N/mm² at 28 days), 0.20% fiber content proved to be the optimum dosage among reinforced mixes, achieving 31.0 N/mm² at 7 days and 32.0 N/mm² at 28 days. Increasing the fiber beyond 0.20% (to 0.30%) caused a noticeable drop in strength due to reduced workability and fiber balling. Thus, 0.20% Recron fiber is identified as the ideal content for optimal mechanical performance.

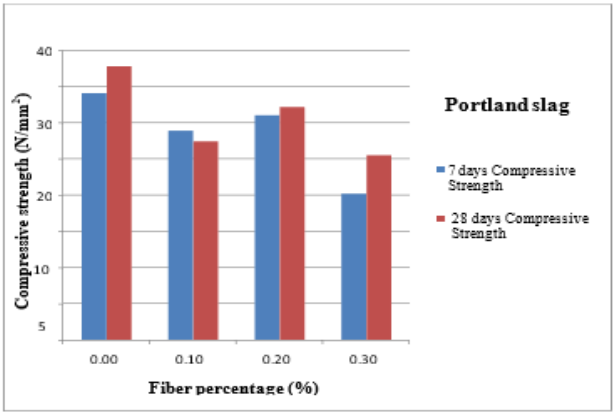



**Fig (4)- Effect of Recron Fiber on Compressive Strength**

## V. CONCLUSION

*1) Recron Fiber improved the mechanical properties of concrete.*

*2) The optimum Fiber content was found to be 0.2%.*

*3) The combination of 20% Silica Fume and 0.2% Recron Fiber provided the best overall performance.*

*4) Silica Fume significantly improved strength and durability characteristics.*

*5) Porosity and capillary absorption were reduced with Silica Fume incorporation.*

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